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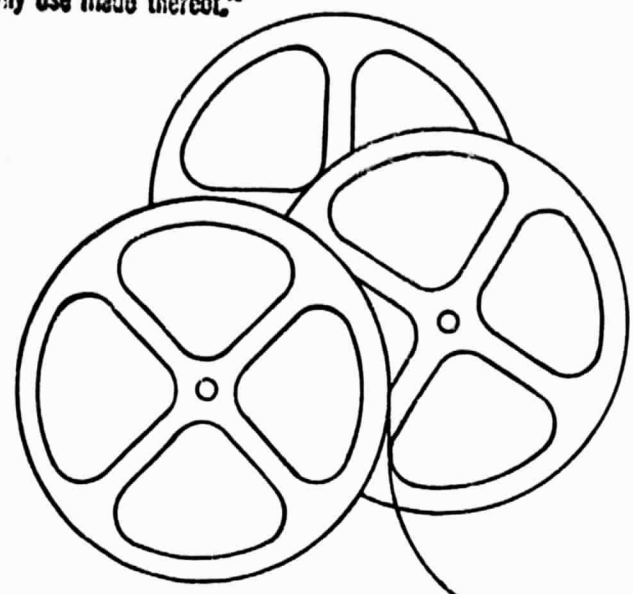

EARTH OBSERVATIONS DIVISION
EARTH RESOURCES DATA ANALYSIS CAPABILITIES

SPACE AND LIFE SCIENCES DIRE

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Foreword

The objective of this capabilities document is to present a concise description of all Earth resources data reduction and analysis equipment and programs available within the Earth Observations Division, Space and Life Sciences Directorate of the Lyndon B. Johnson Space Center, National Aeronautics and Space Administration. This publication, then, is an accumulation of information extracted from the various areas of capability in the Earth Observations Division. Each described capability has been written, reviewed, or edited by personnel in the respective area of capability. The document was compiled and prepared by Lockheed Electronics Company, Inc., Systems and Services Division, Houston, Texas.

It is recognized that a single point of contact is required for additional information on the capabilities described in this document. The Data Research and Control Facility has been selected as the appropriate point of contact for this information. Additional information on any of the documents listed in the bibliography section for each area of capability may be obtained from R. D. Bratton, Systems and Facilities Branch, NASA/SF6, Lyndon B. Johnson Space Center, Houston, Texas 77058.

Because of the dynamic nature of data reduction and analysis capabilities in the Earth resources technology, this document has been formatted to facilitate the addition of changes or new material and the removal of obsolete material as changes in the capabilities occur. It will be updated in the future as required.

D. H. Hay, Chief
Systems and Facilities Branch
Earth Observations Division

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Contents

Introduction

This document presents a summary of laboratory capabilities within the Earth Observations Division (EOD), Space and Life Sciences Directorate, Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA). Electronic, photographic, cartographic, and data services capabilities for processing Earth resources data are described. General descriptions of the hardware and brief descriptions of the computer software are given to identify the capabilities in each area.

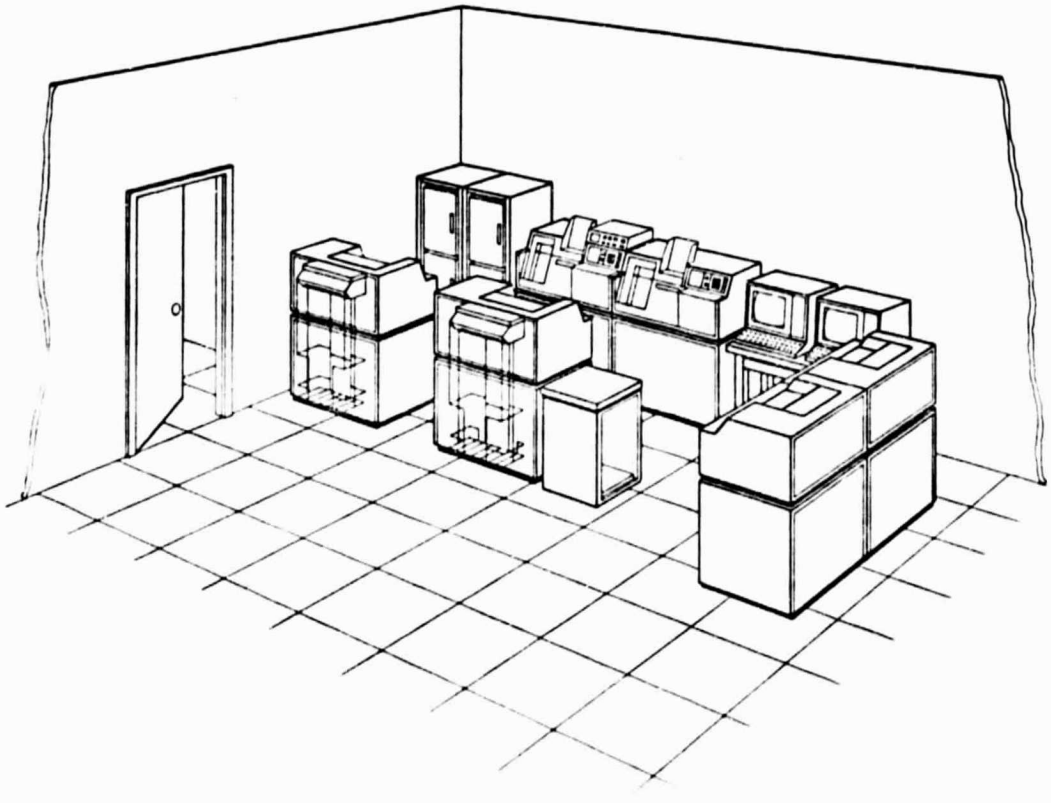
This fourth edition reflects the equipment and computer programs existing as of January 1979. It is intended for use by EOD personnel in planning and developing data handling and analysis tasks. In addition, it is an effective overview of the Earth resources processing capabilities for newly assigned personnel on EOD projects.

Purdue Terminal Facility

GENERAL

The Purdue University's remote-terminal data-communications facility at JSC provides the user a direct link to an IBM 370/148 computer located in the Laboratory for Applications of Remote Sensing (LARS) at Purdue University.

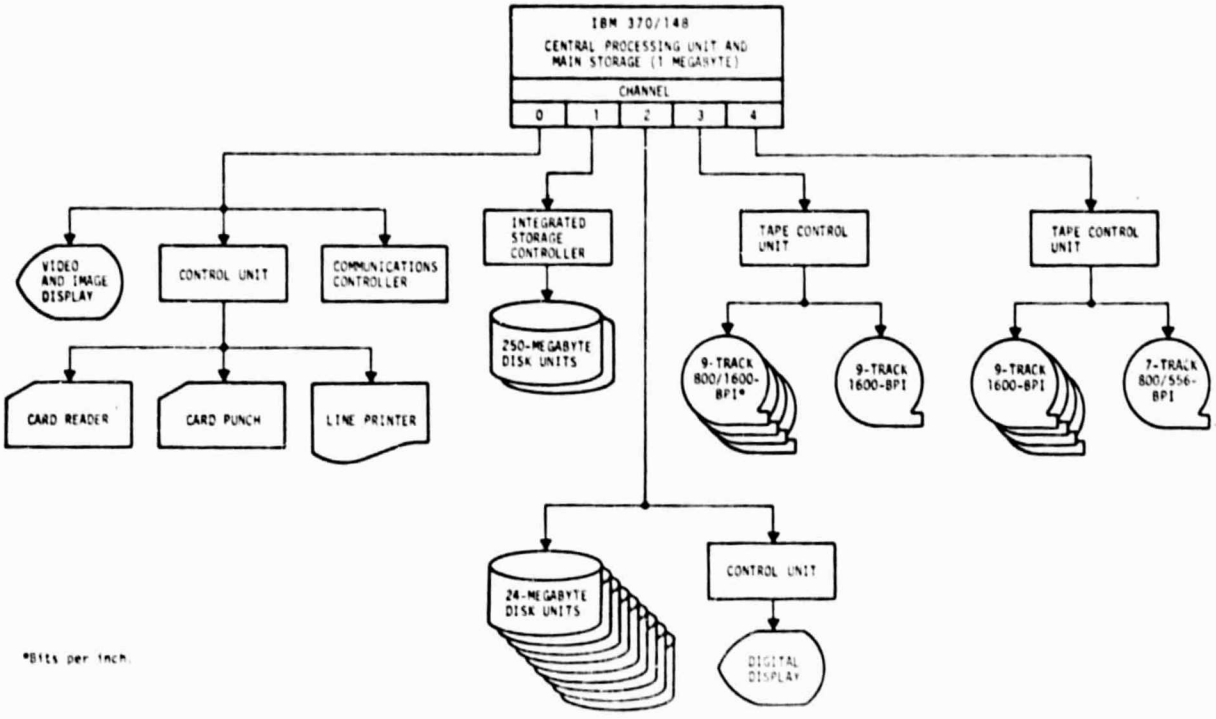
Data in the forms of punched cards or magnetic tapes, or data input on a remote terminal, may be evaluated using current LARS System (LARSYS) techniques. The LARSYS outputs plots, magnetic tapes, line printer listings, and punched cards. Results may be viewed on the cathode-ray tube (CRT) at remote terminals. In addition, the user may obtain graphs, data histograms, and tables of printed data values from the line printer. Users should secure available training information and/or attend training sessions before attempting to use the facility.



Purdue Terminal Facility at JSC.

HARDWARE

JSC and its support contractor personnel have access to one IBM 2780/2 data terminal, two IBM 2741 data terminals, two Hazeltine 2000 data terminals, a Data 100 system, and various dial-up terminals within and outside JSC Building 17. Terminals are operated on a nonscheduled basis, and terminal communication is multiplexed; hence, all terminals may be operated simultaneously. Line printer copies of executions are provided.



Hardware configuration for LARS IBM 370/148.

SOFTWARE

The LARSYS is a multispectral scanner (MSS) data analysis system consisting of sequential iterative processing functions which use pattern recognition and interactive data handling techniques. Software systems in use include LARSYS Version 3.1; the EOD Version of the LARSYS (EOD-LARSYS); JSC and LARS utility programs; and certain stand-alone programs developed at JSC which support pattern recognition techniques (such as Procedure 1) and general mathematical and statistical techniques. The latter group includes the generalized linear model analysis of variance (GLMAOV), CLASSY, minimum loss classifier, and uniform chromaticity programs and the Label Identification From Statistical Tabulation (LIST) Processing System.

LARSYS Version 3.1

MSS images in LARSYS format are on tape files at Purdue. From a remote terminal, particular files can be examined, training fields selected, and interactive processing performed with hardcopy documentation available at each step. Processing functions, options, and data are input by transmission of punched cards. The following is a brief discussion of the 19 data processing functions and programs.

CLASSIFYPOINTS

The CLASSIFYPOINTS program uses a maximum likelihood classification rule to classify data from a multispectral image storage tape on a point-by-point basis. As the basis of classification, a statistics file obtained from the STATISTICS or CLUSTER program is required input. The program outputs a point-by-point classification map and identification record, training fields, classes, channels, and statistical summary information in tabular form.

CLUSTER

The CLUSTER program uses an unsupervised classification (clustering) algorithm to classify individual data points of selected training fields into a preselected number of clusters. The algorithm is based on the distance relationships between each point and the center of the groups of points (cluster to which it belongs). This program outputs a map of clustered arrays, a statistics listing, histograms, the calculated separability of each pair of resulting classes, and a recommended grouping of classes based on separability quotient values.

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COLUMNGRAPH	The COLUMNGRAPH function graphs data values for requested columns from the multispectral image storage tape. The data values are plotted as a function of spatial position.
COPYRESULTS	The COPYRESULTS function copies selected classification results files to tape for selective storage. A results file may be copied on tape from disk or from another tape.
DUPLICATERUN	The DUPLICATERUN function copies a run from the multispectral image storage tape to another tape.
GRAPHHISTOGRAM	The GRAPHHISTOGRAM function generates graphs from a histogram file computed by the HISTOGRAM, IMAGEDISPLAY, or PICTUREPRINT program.
HISTOGRAM	The HISTOGRAM program produces histograms of the spectral values for selected channels from the multispectral image storage tape. The data from this input tape are reduced to the summation of the total number of data values which fall within the automatically centered range of any of 100 equal-sized bins. The file of histograms is stored on the temporary disk and also may be punched on cards. In addition, the HISTOGRAM program prints histogram summary information and statistics.
IDPRINT	The IDPRINT function prints a listing of the identification record of multispectral image storage tape runs.
IMAGEDISPLAY	The IMAGEDISPLAY program prints data in image orientation to enable a user to select manually data which will be useful as training fields for classifier design and as test fields for classification evaluation. IMAGEDISPLAY supports a 16-gray-level display device and also has the capabilities to histogram areas, to graph histograms, and to print the locations of previously defined training and test fields.
LINEGRAPH	The LINEGRAPH function graphs data values for requested lines from the multispectral image storage tape. The data values are graphed as a function of spatial position.
LISTRESULTS	The LISTRESULTS function produces a listing which summarizes the contents of a tape containing classification results files.

PICTUREPRINT

The PICTUREPRINT function reads data from the multispectral image storage tape and produces pictorial printouts of the data for each specified channel. The pictorial map uses alphanumeric symbols to simulate gray-scale tones. The pictorial printout is used to select test and training fields to be processed by other functions.

PRINTRESULTS

The PRINTRESULTS function provides a variety of printed outputs describing the classification results produced by the CLASSIFYPOINTS function.

PUNCHSTATISTICS

The PUNCHSTATISTICS function produces a punched deck of the statistics file that is contained in the classification results file.

SAMPLECLASSIFY

The SAMPLECLASSIFY function uses the mean vectors and covariance matrices computed by the STATISTICS function to classify samples from the multispectral image storage tape by a statistical distance measure. Processor output includes the identification record and classification performance in tabular form.

SEPARABILITY

The SEPARABILITY function helps the user select the set of channels that will produce the most accurate classification using the CLASSIFYPOINTS function. Each set of channels is ranked by either average or minimum transformed divergence of the class pairs.

STATISTICS

The STATISTICS function calculates statistics for selected training fields from data values on the multispectral image storage tape. The function calculates the mean and standard deviation, the covariance matrix, and the correlation coefficients of data values for user-selected channels. Processor output includes a punched card statistics deck, histogram spectral plots, and mean vectors and covariance matrices.

TRANSFERDATA

The TRANSFERDATA function prints, punches, and/or records on tape data values from the multispectral image storage tape. Data are converted to Fortran for use in other programs.

Batch

The LARSYS also supports batch processing.

JSC Utilities

TRNSFR	The TRNSFR program directs the transfer of tapes from JSC to LARS.
TOHOUS	The TOHOUS program directs the transfer of tapes from LARS to JSC.
PUNCC	The PUNCC program punches a control card for the JSC Data 100.
TRFAST	The TRFAST program reads in the punched cards sent by JSC during a tape transfer to LARS.

LARS Utilities

HEADER	The HEADER program guides the printing of the Universal- or LARSYS-formatted header record.
GCMNDS	The GCMNDS program processes control cards for the HEADER routine.
FTORD	The FTORD program eliminates duplicate files and tape requests from the SEGFO program.
GETACQ	The GETACQ program mounts and positions a tape to the file containing a given acquisition.
SEGFO	The SEGFO program returns a data cross section indexed by segment number and acquisition date.
POS	The POS program positions a tape to a given file.
UNIFIL	The UNIFIL program fills a buffer and determines the tape format.
UNVSAL	The UNVSAL program prints the header record of a tape in Universal format.
ENCHAR	The ENCHAR program removes invalid print characters from a string.
LFHEAD	The LFHEAD program prints the identification record for a tape in LARSYS format.

EOD-LARSYS

The EOD-LARSYS is a batch processing system composed of a system monitor and a set of processors, each of which performs a specific function in the analysis of MSS imagery data (as described below). Data are preprocessed on the Large Area Crop Inventory Experiment (LACIE) System,[1] which creates a multipass image data tape by merging raw image data tapes received from the Goddard Space Flight Center (GSFC). The EOD-LARSYS accepts computer-compatible tapes (CCT's) in the ERTS-1,[2] LARSYS II or III, or Universal format. Processors are linked by files on disk or tape or, less commonly, by card decks. The execution of a particular batch job may begin or end with any processor, provided the appropriate files are furnished.

HIST

The histogram (HIST) processor computes individual field histograms and a total histogram for all the fields and channels defined by the user. An individual statistics report containing field descriptions, data ranges, means, standard deviations, and normalized ranges (means and standard deviations) is printed for each field and for the combined fields.

GRAYMAP

The GRAYMAP processor produces alphanumeric pictorial printouts of digitized MSS data. To allow a meaningful distinction in gray-scale tones, it assigns 1 of 16 possible symbols to each picture element (pixel). The symbols may be preassigned or arbitrarily assigned for each run. The specification of the bin edges for each symbol may be assigned arbitrarily by the user for each run or computed from the histogram data so that equal activity for each of the symbols results. The data are output in terms of symbols, each symbol representing a range of data values in which the corresponding data points fall.

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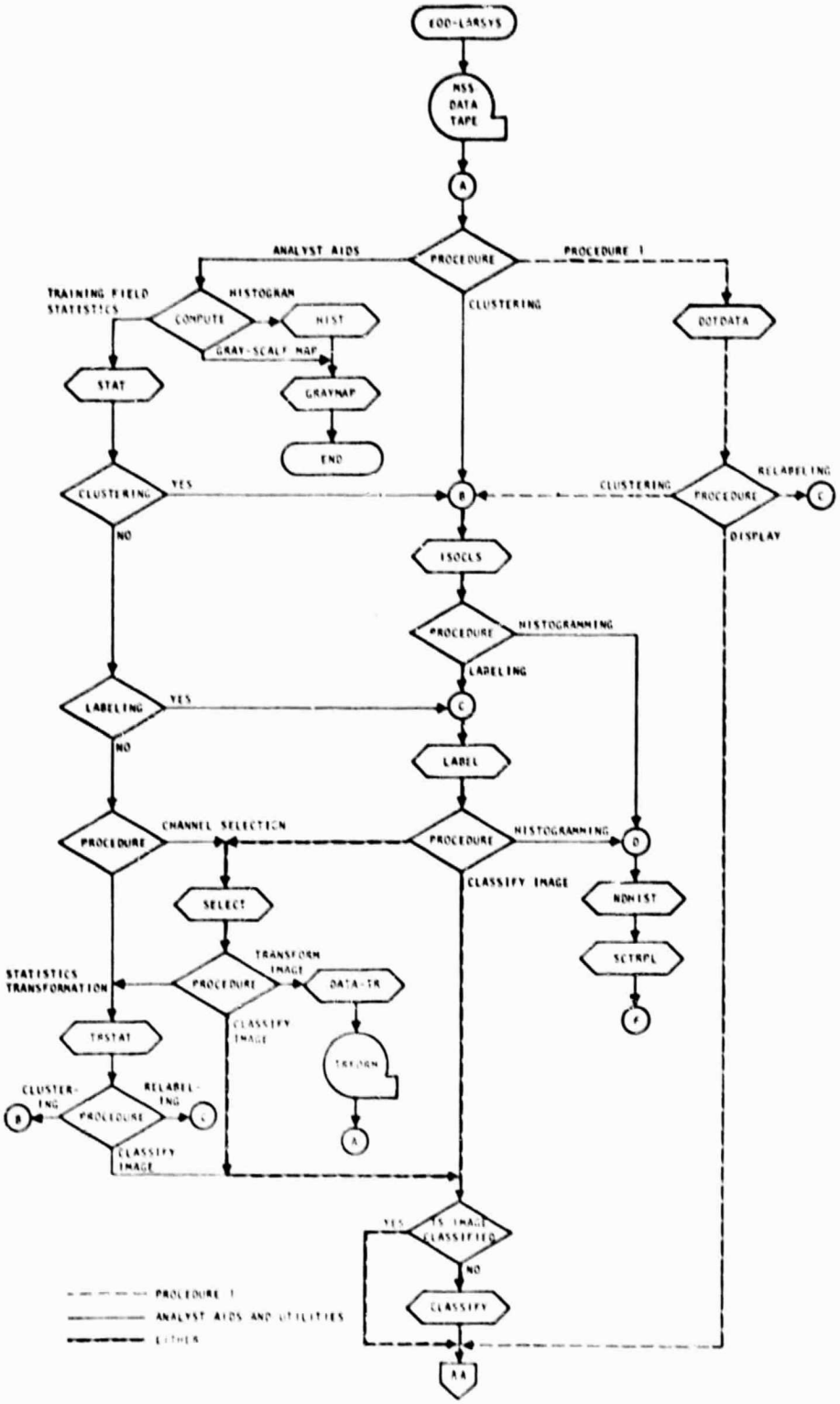
[1] Formerly Earth Resources Interactive Processing System (ERIPS).

[2] The first Earth Resources Technology Satellite, later renamed Landsat-1.


EOD-LARSYS
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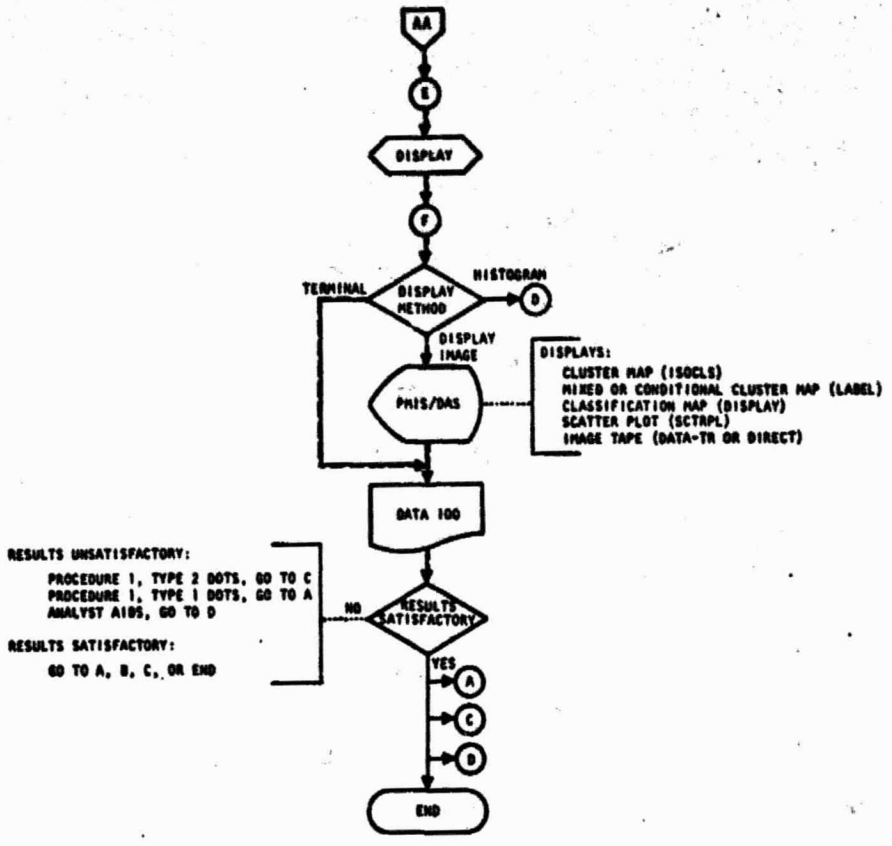

Major processing paths in the EOD-LARSYS — Concluded.

STAT

The statistics (STAT) processor computes the multichannel means, standard deviations, covariance matrix, and correlation coefficients for each training field and all training subclasses which are defined through user input to the processor. In addition, at the user's option, histograms and spectral plots may be computed for each field and/or subclass.

CLASSIFY

The CLASSIFY processor classifies the MSS image data based on statistics computed from the training fields. It accepts the Universal- or LARSYS-III-formatted MSS data tape, training statistics from the STAT processor, a B-transformation matrix, and field definition card images. Given the statistics for each subclass of interest, CLASSIFY assigns each data point within the specified field to a subclass, using either the standard m-class maximum likelihood

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classification or the sum-of-normal-densities rule. In support of Procedure 1, CLASSIFY obtains subclass *a priori* values and assigns category names using subclass population and class name data from the input statistics file. It prints a line printer map of the classification data, with each classified point represented by a symbol, and outputs the results to the classification map tape file for use in the DISPLAY processor.

DISPLAY

The DISPLAY processor accepts the classification map tape file output by the CLASSIFY processor or the dot data file output by the DOTDATA processor, performs various functions in the classification process, and displays the results. The results generated on the line printer include a classification summary and a map of each classified field; an intensive test site (ITS) summary report; classification performance summaries for ground-truth areas within the classified image; or, if in the dot processing mode, dot data classification performance summaries. Optionally, it generates a tape of the classified image for display on the Passive Microwave Imaging System/Data Analysis Station (PMIS/DAS).

ISOCLS

The Iterative Self-Organizing Clustering System (ISOCLS) processor clusters data by determining the nearest cluster center to a pixel and assigning the pixel to that cluster. After an assignment is completed, new cluster centers are determined and the process is repeated. A class consisting of one or more fields is input from the MSS image data tape. The number of classes that may be clustered is limited to 75 (if the statistics file from the STAT processor is used) or to 60 [if feature selection (SELECT) or CLASSIFY processor output is used]. If in the Procedure 1 mode, ISOCLS requires a statistics file, initial cluster centers on card images, and starting dots as output by the DOTDATA processor. ISOCLS outputs a statistics file, a printout of cluster results, and (optionally) a cluster map tape for displaying results on the Bendix 100 Interactive Drafting System (IDS) or on the PMIS/DAS.

TESTSP

The TESTSP processor is an iterative self-organizing clustering system which clusters pixel values and stores them on disk in packed form (one pixel value per byte) rather than in floating point form (one pixel value per four bytes).

DOTDATA

The DOTDATA processor was developed to facilitate LACIE Procedure 1, in which pixels or dots are labeled instead of training fields (the analyst-aids procedure). DOTDATA creates a data file of labeled dots on tape. This file is an interface to the ISOCLS, automatic cluster labeling (LABEL), and DISPLAY processors for clustering, cluster labeling, and displaying results, respectively.

SELECT

The SELECT processor accepts a statistics file from either the STAT or ISOCLS processor, measures the relative importance of the individual channels (features), and outputs the set of channels which provides the best discrimination between subclasses. The user chooses either the weighted average interclass or transformed divergence or the weighted average Bhattacharyya distance to measure the separability of subclasses. The Exhaustive Search, Without Replacement, or Davidon-Fletcher-Powell procedure is used to select the best set of channels. SELECT also outputs the B-transformation matrix for later input to the CLASSIFY, data transformation (DATA-TR), scatter plot (SCTRPL), SELECT, and/or statistics transformation (TRSTAT) processor.

DATA-TR

The DATA-TR processor transforms images from the MSS image data tape by performing a linear transformation on user-defined fields. One of three methods is used to effect the transformation: the histogram or the statistical method, in which data are rescaled, or a method utilizing user-input scaling parameters. The transformed or rescaled data are output on tape in Universal or LARSYS II format, along with a line printer plot of the histogram (if applicable).

TRSTAT

The TRSTAT processor uses the data produced from the STAT and/or ISOCLS processor to transform the means and covariances of the clusters. The transformed statistics are output to tape.

LABEL	The LABEL processor supervises the labeling of statistics obtained from the ISOCLS processor or the relabeling of files from the DOTDATA processor. At the analyst's option, one of two labeling methods is selected: the k-nearest-neighbor or the all-of-a-kind procedure. LABEL outputs a conditional, unconditional, or mixed cluster map to tape. The labeled statistics or the relabeled dot data are output on the line printer.
NDHIST	The N-dimensional histogram (NDHIST) processor uses all channels (plotting and color) to calculate the histogram. It extracts the necessary information for each pixel in a field and arranges these data for input to the SCTRPL processor.
SCTRPL	The SCTRPL processor reads the N-dimensional histogram file output by the NDHIST processor, determines the location of each unique data vector on the scatter plot, and outputs the spectral plot to tape in Universal format. A line-printer pixel-frequency scatter plot also may be output.
DAMRG	The data merge (DAMRG) processor merges Universal- or LARSYS-formatted MSS data files suitable for input to pattern recognition systems. User options determine which of the three merge capabilities (channel, spatial, or line) will be utilized.
GTDDM	The ground-truth dot dump (GTDDM) processor uses the converted ground-truth tape from the ground-truth tape conversion (GTTCN) processor to label the 209 grid points or dots in the field. A dot card file in the LACIE format is made for each ground-truth image file. Inputs to the program via card image are a crop-code-to-category transformation data set and a card image specifying type 1 or 2 dots and label type.
GTTCN	The GTTCN processor converts input ground-truth Universal-formatted image tapes containing 392 samples and 351 lines to Universal-formatted LACIE image size containing 196 samples and 117 lines.
UTILITIES	Forty-nine utility subprograms support the various EOD-LARSYS processors. (See section 19 of Volume III of the EOD-LARSYS User Guide for the IBM 370/148 for a description of the utility subprograms.)

JSC Stand-Alone Support Programs

CLASSY

The CLASSY clustering program implements a new iterative statistical clustering algorithm which predicts the number of pure classes in classifying Earth resources remotely sensed data. The outputs of the program are a line printer map with symbolic representation for the clusters and a cluster map on disk or tape.

GLMAOV

The GLMAOV program implements an analysis of variance for experimental designs. The program completes an analysis of variance for unbalanced designs, designs with missing data, and designs with multiple solutions. The program is in a general form and includes analyses of covariance and regression. Pseudoinverses of the model matrices required in the analyses are computed using an algorithm identified as Greville's Method.

LIST

The LIST Processing System features a semi-automatic dot labeling procedure. The quadratic discriminator is trained based on analyst-furnished responses to questions concerning the segment under investigation and individual dots, raw MSS data, and ground-truth dot labels. This discriminator is used in the test and classification phases to label dots utilizing the analyst-supplied responses.

MINIMUM LOSS CLASSIFIER

The minimum loss classifier program computes a loss matrix using the input data and then uses the matrix to classify the data into one of two classes. The program is operational in either the interactive or batch mode.

UNIFORM CHROMATICITY

The uniform chromaticity program applies the uniform chromaticity scale transformation of Kauth components to Landsat imagery data. The resultant data are output to a Universal-formatted file.

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Earth Resources LACIE System

GENERAL

The Earth resources LACIE System is an interactive graphics system used in processing and investigating remotely sensed Earth resources data. It is designed to process data from various imaging sensors and allows the analyst to interpret data as processing takes place. The system can be easily modified to support various types of sensor data.

The LACIE System evolved from the ERIPS, which was developed and placed in operation at JSC in 1974, with a set of remote terminals connected to the IBM 360/75 computer in the Real-Time Computer Complex (RTCC), JSC Building 30. Its purpose was to allow user-machine interactive processing of remotely sensed data by means of area mensuration, image handling, batch production, classification from multi-image disk storage, and classification character mapping for printer output. Its capabilities were enhanced to include cursor and image positioning and a wide variety of statistical computations to achieve pattern recognition, clustering, signature extension, remote field definition, and image registration.

The ERIPS emerged as a comprehensive facility for processing multispectral remote sensor data. Its widespread use in the EOD fostered the addition of a set of terminals in the Data Techniques Laboratory (DTL) in late 1974. From 1974 through 1977, the ERIPS capabilities were enhanced to accommodate the LACIE; and the system came to be used exclusively for LACIE processing. These events brought about a change from ERIPS to the present system nomenclature.

The LACIE System is capable of processing remotely sensed data from various imaging sensors, including the Landsat 16-channel MSS and return beam vidicon (RBV), the Multispectral Camera System (MCS) 24-channel scanner, the Earth Resources Experiment Package (EREP) 13-channel scanner, and the Michigan 12-channel scanner. It can be easily modified to support additional sensors.

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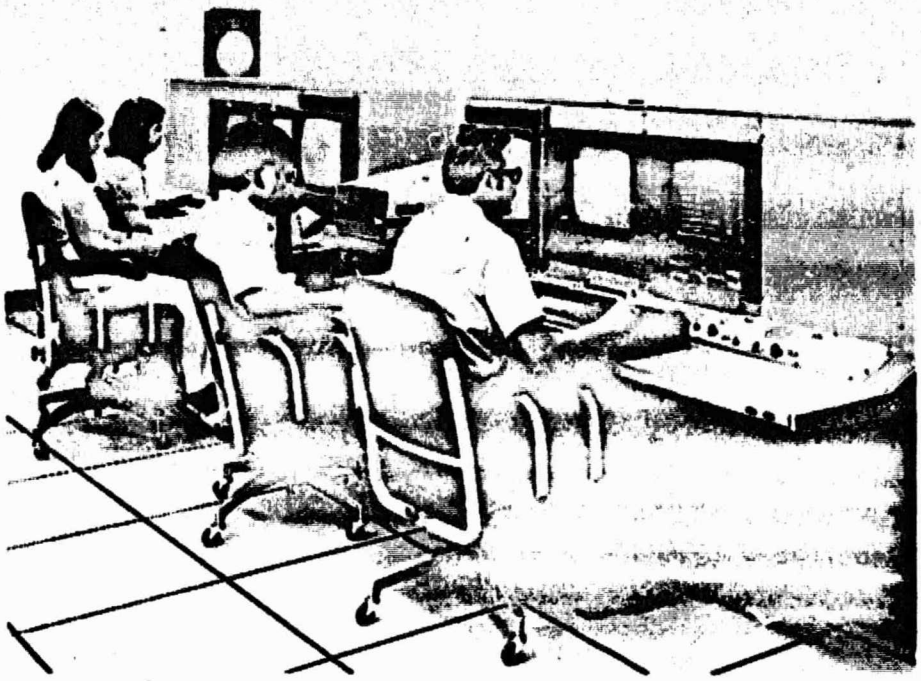

LACIE System terminal in the DTL.

Interaction between the user and the computer is established through the conversational monitor. The monitor displays menus from which the user, through the keyboard and cursor control, can choose the many options involved in image registration and spectral pattern recognition. Almost instantaneous responses to user choices of features, channels, and computations are provided. The user can also control and vary image intensity, and user selections and computer responses may be hard copied for future reference.

HARDWARE

The basic LACIE System is composed of an IBM 360/75 computer in the RTCC connected to two sets of special terminals. Sensor data are supplied to the system on 9-track, 800-bit-per-inch (bpi) CCT's in the Landsat MSS bulk or LARSYS or Universal format. Online storage consists of 7330-disk data bases for storing and retrieving historical, fields, and image data. The system also requires a disk drive and a special-purpose processor.

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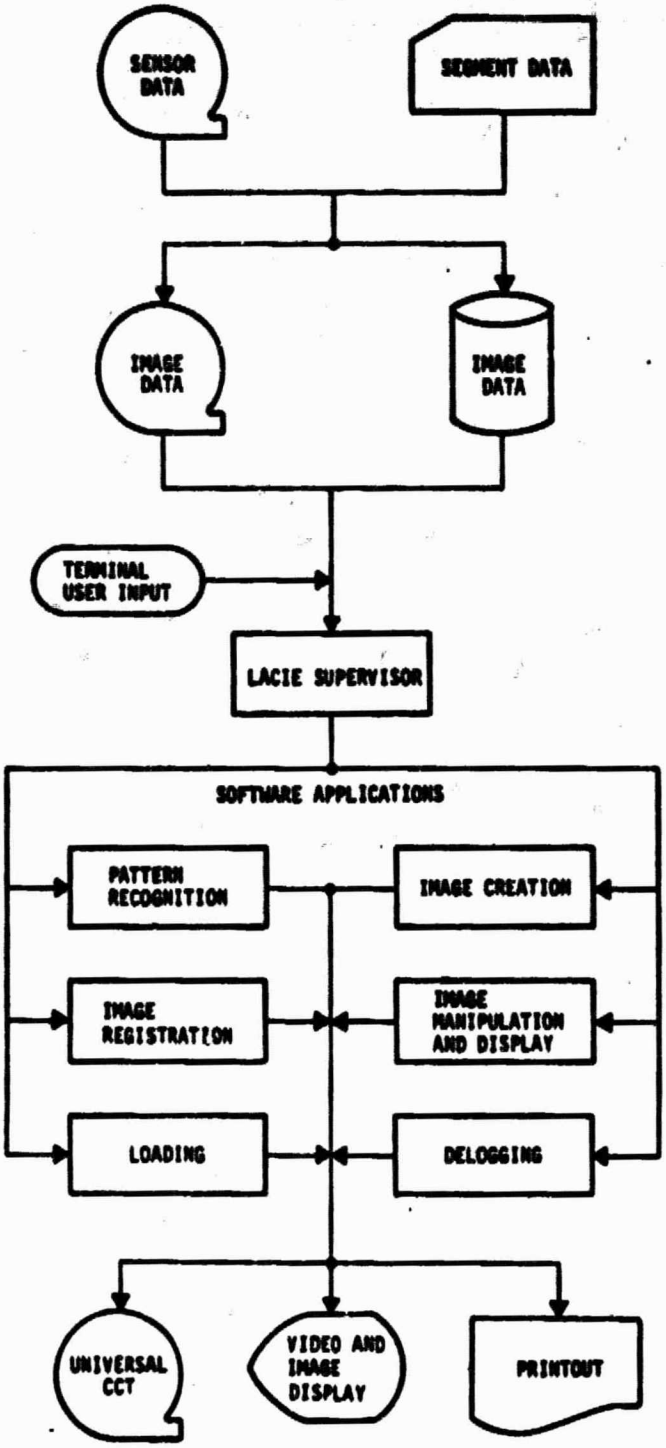

Diagram of LACIE System organization.

Each set of remote interactive terminals has one color and two black-and-white display screens. The black-and-white conversational screen is a communication device between the user and the system. English language instructions and options are displayed, along with system status and error information. The other screen, the image screen, is a landscape monitor for displaying black-and-white images; it has a resolution of 16 gray levels with 439 lines of data and 612 pixels per line. The color image monitor also has 439 lines with 612 pixels per line for displaying color images. A keyboard is used to input information, or the cursor control is used to point at a location on the image screen. The two sets of interactive terminals may not be used simultaneously.

SOFTWARE

The primary analysis software packages currently available for use are the pattern recognition application, which performs multispectral analysis, and the image registration application. In addition, LACIE software also covers the following applications:

- Loading
- Image manipulation and display
- Delogging
- Image creation
- Batch processing

Pattern Recognition

The pattern recognition application applies random processes to digitized multispectral image data for the classification of unidentified data and is based on the LARSYS. Thirteen modules, each with a distinct function, are utilized in LACIE pattern recognition. The order of their execution is determined by keyboard or cursor entries, and image data are read from disk storage as specified by the user.

The system outputs reports interactively to the conversational screen and classification maps to the image screens.

Image Registration

The image registration application allows the user (1) to register two images together, (2) to register an image to a latitude-longitude grid, (3) to perform explicit image manipulation, and (4) to perform automatic correlation of two images.

Three outputs may be obtained from the image registration computation: a display of the final registered image (located in the core) on the color or black-and-white landscape monitor, microfiche of the final registered image through normal LACIE-associated hardware, and a Universal-formatted CCT of the final registered image.

Loading

The loading application allows the user (1) to transfer image data from CCT into system disk storage for analysis, (2) to unload image data from disk to CCT for future use, (3) to view an image directly from CCT and select the portion he wants loaded by using the graphicon pen to indicate the area on the screen, and (4) to view a report of header information for any image.

Image Manipulation and Display

The image manipulation and display application may be used independently or with other LACIE applications. It allows the user to display an image on the landscape monitor with a maximum of 16 shades of gray on the black-and-white screen or 64 colors on the color screen and to manipulate the image by scrolling and magnification.

Using this application, the user can retrieve image data from disk and output reports to the video screen; images, histograms, and scrolling to the image screen; and gray or color images to CCT.

Delogging

The delogging application allows the user to generate a printed copy of all or selected menus or reports. The printed report is automatically sent to the user's address on the sign-on menu.

Image Creation

The image creation application allows the user (1) to combine two identical images to form a third, (2) to use the difference between two images to form a third, (3) to merge two separate images to form a third, (4) to take the division of two specified channels on an image and multiply it by a specified constant to form a new image, and (5) to form a new image from the subset of an existing image.

Batch

The LACIE System also performs batch processing and outputs Universal-formatted nine-track CCT's, line printer listings, and color photographs and microfiche of image displays.

The batch input processor is an offline method of building menu inputs for LACIE batch production processing of recognition segments. Cards are read by the processor, and the data are stored on disk or used to build a CCT for input to the LACIE System. Batch processing is used to load and update the Process Control Data Base, which contains all data on LACIE recognition segments, and to generate a Classification and Mensuration Subsystem (CAMS)/Crop Assessment Subsystem (CAS) Interface Tape (CCIT).

Utilities

The LACIE System also has a set of standard utilities which are used primarily to update and maintain the LACIE data bases. These utilities allow the user:

- To enter remote field definitions
- To convert Universal-formatted to LACIE-formatted images
- To construct a multifile image tape in Universal format to be used by the production film converter (PFC)
- To process a GSFC image tape for LACIE
- To create, update, and report on the Fields Data Base
- To build and maintain the Dot Data Base in support of LACIE Procedure 1

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IMAGE 100

GENERAL

As delivered by the General Electric Company to JSC in December 1974, the Interactive Multispectral Image Analysis System (Image 100) was oriented toward the analysis of four-channel Landsat MSS images. Since its original delivery, most of the programs have been modified, and additional processing systems and special programs have been added, resulting in an extensive elaboration of the General Electric version. A multiuser environment has been implemented by its interface with the Programmed Data Processor, Model 11/45 (PDP 11/45), and the Resource Sharing Executive, Model 11D (RSX-11D). Additional disk storage has increased program capacity.

The Image 100 is a highly interactive system which, through man-machine communication, enables the analyst to make many decisions while processing digital imagery data.

The Image 100 accepts multichannel imagery on nine-track digital tape in the Landsat MSS bulk or Universal or LARSYS format. The system was designed primarily for four-channel imagery with the fifth channel reserved for theme storage. Therefore, when more than four-channel data are processed, only four channels at a time will normally be loaded into the refresh memory. In addition to the nine-track tape capability, the system is equipped with an input scanner unit for digitizing and displaying data on the CRT screen. The scanner accepts photographic prints or transparencies in color or black and white and has three filters for color digitizing. The digitized data are loaded into the refresh memory and therefore may be analyzed as if loaded from tape.

The basic Image 100 possesses the following special capabilities:

- Interactive training mode enabling the user to interact with data on a real-time basis.
- Signature analysis for any number of thematic classes; as many as nine themes may be displayed simultaneously.

- Display of processed results (themes) in enhanced form on color CRT within seconds.
- Discrimination technique which is easily modifiable by the user to eliminate misclassifications.
- Integral, high-speed, special-purpose, parallel processing circuitry.
- Simultaneous four-channel (or five with preprocessing) parallelepiped or histogrammed signature analysis.
- Multiple user-selectable preprocessing modes used on each pixel in the image; i.e.:
  - Normalization
  - Ratioing techniques (two)
  - General-purpose transformation
  - Shading correction
- Bulk processing mode allowing rapid classification of total flight-line or Landsat image from magnetic tape (requires addition of software).
- Split-screen format permitting display of preprocessing, training, and classification results over large noncontiguous geographical areas while maintaining large-scale resolution.
- Multiple input modes:
  - Color and color-infrared photographs
  - Multiband black-and-white photographs
  - Digital tapes
- Wide variety of outputs:
  - Color CRT display
  - Graphics display terminal for exhibiting alphanumeric text, graphics, and clusters
  - Line printer output for producing hardcopy digital maps, contour plots, graphics, and data tabulations
  - Digital theme tapes

HARDWARE

The items of equipment which support the multi-user environment of the Image 100 allow an analyst to receive images on tape, to display the images, to classify them, and to display the results. The following equipment supports the basic Image 100 functions.

- Image 100 controller — the large console and related equipment, including the 21-inch color CRT and the refresh memory. The console contains a video display panel for exhibiting binary images (themes), a preprocessor and theme synthesizer panel for scaling and combining themes, a power setup and overlay panel, a magnification panel, and the special functions switches which control the most frequently used programs in the system.

- Tektronix terminal — the teletype keyboard with a graphics screen; used by the analyst to select certain programs, to respond to questions by programs, and to control other functions (i.e., to take part interactively in the classification process).

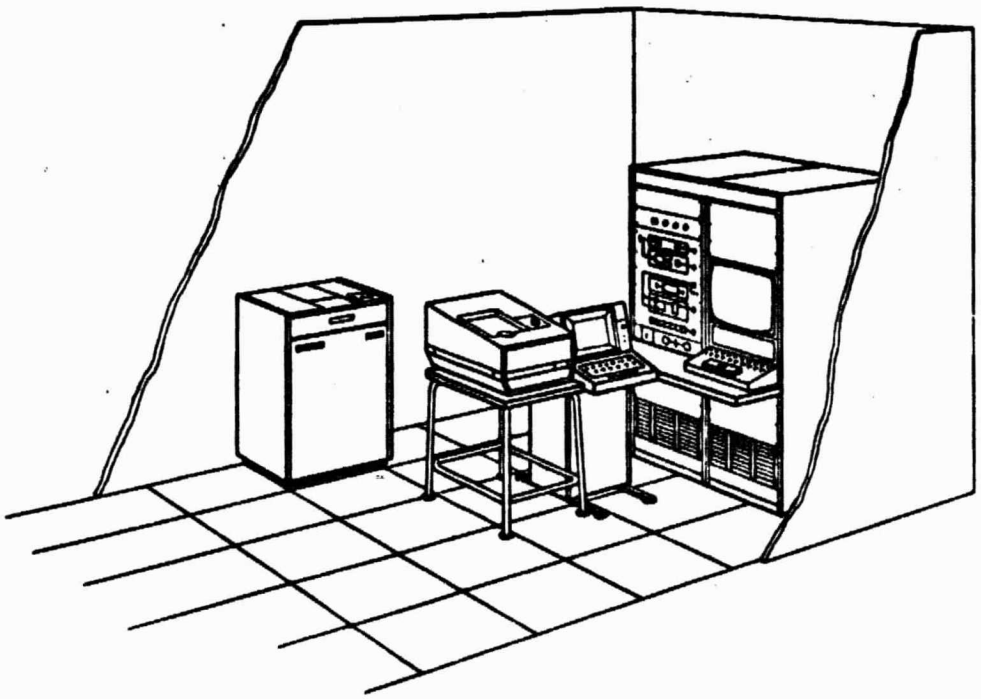
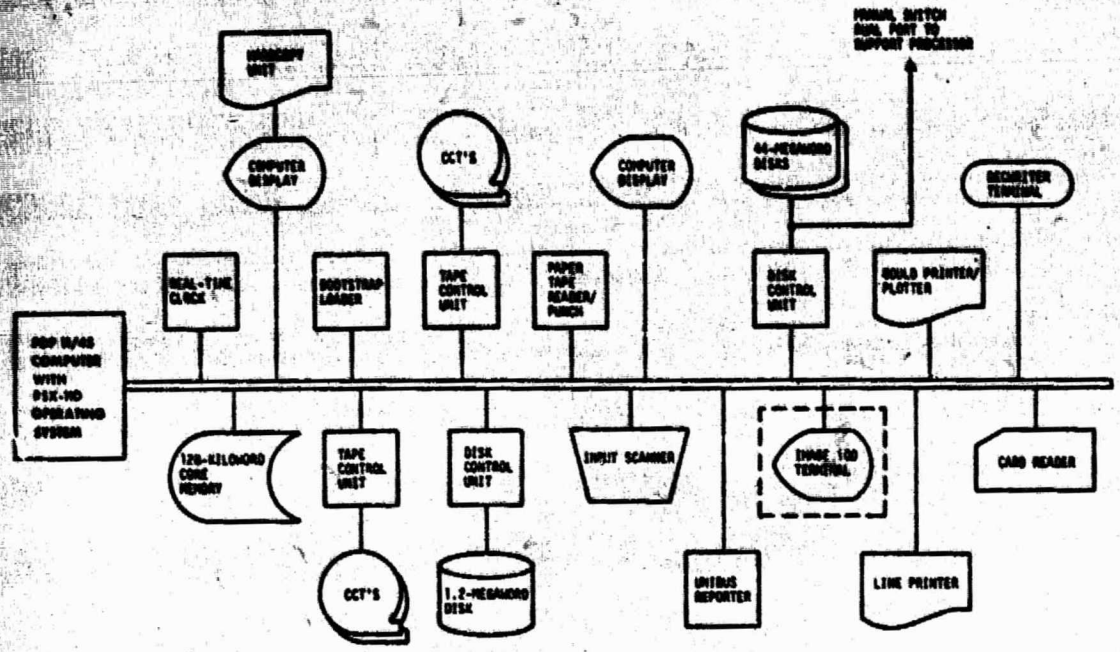


Image 100 console with terminal, hardcopy unit, and printer/plotter.



Hardware configuration for Image 100 system.

- PDP 11/45 computer with RSX-11D operating system — the basic computer that controls all functions in the Image 100.

- Magnetic tape controllers and magnetic tape drives — allow images to be read into the Image 100 and some results to be written onto tapes.

Other devices now in the system allow the analyst to perform many additional operations and to work more efficiently; i.e.:

- Input scanner (table scanner) — a movable television camera on an adjustable table that allows visible images in the form of transparencies to be placed in the refresh memory of the system; this is useful for adding political or other boundaries to existing images and for superimposing photographic images when taped images are unavailable (such as with the S-190A multispectral photographs from the Skylab missions).

- Gould printer/plotter — allows an analyst to obtain black-and-white copies of selected results of his analyses immediately.

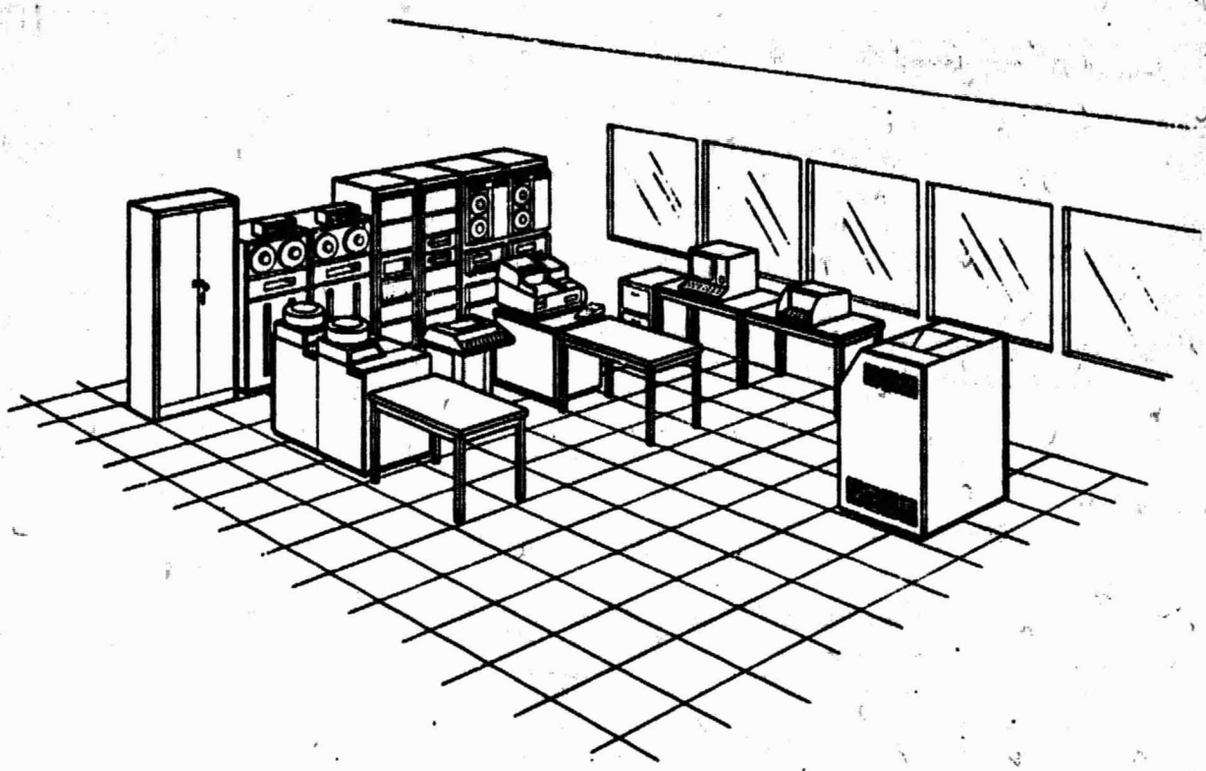


Image 100 system, including PDP 11/45 computer and peripherals.

- **Tektronix hardcopy unit — allows an analyst to obtain an immediate copy of information that appears on the Tektronix graphics screen.**

- **Disks and disk controller — used for storing large quantities of data and maintaining virtually all of the programs read into the Image 100.**

- **Additional tape controller and tape drives — allow the analyst much more flexibility in his use of the system and permit the system to function despite the failure of several tape drives.**

- **Mohawk line printer — allows an economical medium for producing large amounts of tabular data when required by the analyst.**

- **Card reader — for reading certain types of data input on cards.**

- Digital Equipment Corporation (DEC) writer — a teletypewriter that is useful to operators but unavailable for use by analysts.

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SOFTWARE

The programs for the Image 100 cover the following functions.

- Data input and preprocessing.
- Signature acquisition.
- Signature analysis.
- Utility routines which provide various methods for selecting, displaying, modifying, and storing data.
- Data output.
- Input scanner for reading images into the refresh memory.
- Application of LACIE Procedure 1 for obtaining status reports of the data base for interactively defining fields, for dot and cluster labeling, for displaying cluster and classification maps, for producing detailed reports, and for inserting and extracting data into and from the data base.
- Clustering and classification.
- Requalification testing — can be performed on either hardware or software whenever a change in system configuration occurs.

Data Input and Preprocessing

Generally, programs that have the mnemonic may be extracted by the mnemonic and used; those that do not have the mnemonic function are listed as capabilities on the system menu.

PARAMETER MODIFICATION

The parameter modification (PRMTR) program allows the user to modify the functional parameters of the Image 100 executive (i.e., number of channels, number of gray levels, and histogram rejection levels) used in processing the data to be analyzed.

CONSOLIDATED TAPE READ

The consolidated tape read (FULOI) program allows the user to read Landsat MSS bulk data tapes, Universal- and LARSYS-formatted tapes, and images in disk storage on the Image 100.

ERTS OVERVIEW

The ERTS (now Landsat) overview (ERTSOV) program permits loading of an entire Landsat frame (four reels input one at a time) into the refresh memory on a sampled basis. In this way, a user can survey an entire scene before choosing a portion for detailed studies.

HEADER LISTS

The Universal header list (U9TRD), ERTS (Landsat) header list (ERTHED), and LARSYS tape header list (LARSYS) programs display the image tape information in header records.

GENERAL-PURPOSE TRANSFORM

The general-purpose transform (GPT) program transforms or rotates a four-channel image in spectral space in real time as it is read from the refresh memory. The software determines the rotation angles of spectral clusters from each spectral axis via histogram analysis. The coefficients of the 4-by-4 rotational matrix are generated by the software in one of four modes:

- RAW — in which data are passed unchanged through the transform hardware; also referred to as a "unity" transform.
- HADAMARD — in which all rotation angles are 45° and all directional cosines are equal in magnitude.
- EIGENVECTOR — in which eigenvalues and eigenvectors are computed from the covariance matrix, which is derived based on a training sample; the matrix of eigenvectors is the set of coefficients which performs the optimum four-dimensional transformation.
- MANUAL — in which the user selects and enters rotation angles for the six different projection planes, one at a time; after entering each angle, the user observes the CRT display and/or another cluster display to assist in his selection of the next angle.

Signature Acquisition

1-D HISTOGRAM

The one-dimensional (1-D) histogram acquisition program determines the gray-level distributions (pixel counts or frequency of occurrence at each gray level) for each channel independently, thus localising the training area clusters in spectral space; also defines the upper and lower limits of the distributions in each channel under user control.

N-D HISTOGRAM

The N-dimensional (N-D) histogram acquisition program performs a multidimensional histogram cell-by-cell analysis within the spectral distribution limits determined in the 1-D signature acquisition operation. The total number of pixels and the spectral coordinates of each cell are automatically stored under a preassigned file name on the computer disk. The cell size is selected by the operator prior to signature acquisition by using the PARAMETER mode. Upon acquisition, the maximum count number of empty cells is exhibited on the graphics display terminal. These limits plus control panel switch settings are stored after entering the N-D histogram acquisition. The data are stored under a file name previously assigned by the user in the PARAMETER mode. If no name has been assigned, this file is assigned a name automatically by default. A previously stored file can be retrieved by the program, also.

SINGLE-PIXEL TRAINING

The single-pixel training (ONEPIX) program reads the data immediately surrounding and including the cursor (crosshair) position. The data for all four bands are displayed on the terminal in absolute scale (i.e., 1 to 256 gray levels).

Signature Analysis

1-D HISTOGRAM DISPLAY

The 1-D histogram display program effects the display of the 1-D histogram and corresponding data for each channel as obtained using the 1-D histogram analysis subprogram. A maximum of four channels comprising the 1-D histogram are displayable simultaneously (in compressed form) via the graphics display terminal, or a selected channel may be displayed over the full screen. Limits may be modified by using the cursor and keyboard on the graphics display terminal.

SIGNATURE PRINT

The signature print program provides the capability to print out sectional graphs of feature space. Two-dimensional (2-D) slices of the spectral signature are printed on the line printer for each value of the remaining dimensions. Any axis pair may be selected for the 2-D slice, and the remaining dimensions may be cycled in any order.

N-D CLUSTER DISPLAY

The N-D cluster display program provides quick-look capability similar to the signature print program except that only a selected slice (or slices) is output on the graphics display terminal.

MAIN-CELL CROSS-REFERENCE

The main-cell cross-reference program automatically searches the signature file, ranks the histogram cells by pixel count, and prints the results on the line printer after an N-D signature acquisition. The cells are cross-referenced according to spectral separation from one another; 1 indicates adjacent cells, and 5 indicates separation by the equivalent of 5 cells in some direction. This program also allows input of multiple files to build a composite signature for display.

THEME BUILD

The cluster synthesis (theme build) program accumulates spatial alarms under one theme number to permit the synthesis of a theme based on the addition of user-specified cells.

THRESHOLDING

The thresholding program performs the classification function based on training data acquired during N-D signature acquisition. The signature is tested cell by cell against the user-selected threshold (the default threshold is 1); that is, if the pixel count for a given cell is equal to or greater than the threshold value, it is retained; if less, it is discarded. For example, a threshold of 1 would cause all empty cells to be discarded. The result of this testing process is accumulated on an operator-selected theme storage area (default is theme 1). At the conclusion of the theme synthesis, the original parallelepiped limits are set by the computer into the signature analyzer threshold registers so that the alarm will display the results of the original 1-D acquisition.

Utilities

WINDOW DISPLAY

The window display (WINDOW) program provides the capability to select an image area with the cursor, to expand that area by a factor of an integer number, to train on the expanded area on a single-pixel basis (if desired), and to classify the entire 512- by 512-pixel scene. Magnification is achieved by decreasing the cursor size and keeping the insert areas fixed at one-sixteenth of the display area. The portion of the screen overwritten by the expanded area can be restored without further tape input.

SLICER

The slicer (SLICE) program is similar to the contrast stretch (STRCH) program except that, instead of rewriting the video, a (selected) number of themes are generated and written onto the refresh device. The exact range occupied by each theme is reported on the graphics display terminal.

ANNOTATION

The annotation program permits the user to enter alphanumeric text on a theme via the graphics display terminal keyboard for display on the color CRT.

CONTRAST STRETCH

The STRCH program searches the data within the cursor for a given band, determines the maximum and minimum brightness values, and then rewrites the entire band of imagery normalized to these values. The user may input maximum and minimum values as an option.

THEME EXCHANGE

The theme exchange (THEMEX) program performs a theme exchange; i.e., if 1 and 3 are typed on the graphics display terminal, themes 1 and 3 would reverse storage positions on the refresh memory. This helps to achieve a better color balance for photographic purposes.

VIDEO EXCHANGE

The video exchange (VIDEX) program performs the same function as the THEMEX program except that it operates on complete channels of imagery. The eight themes are treated as one channel (band 5).

THEME AREAS

The theme areas (AREA) program reads the theme "totalizers," which are the digital counts of the themes, the alarm, and the alarm gate. These are expressed in CRT element counts, as well as in the percentage of the total display area.

LOGGING FILE

The logging file program creates a file of all operations performed during machine training on the computer disk or other storage media, provided the LOG switch is set (specified by the user during PRNTR program execution). Data recorded include (but are not limited to) the status of all control panel pushbuttons and thumbwheel switches, parallelepiped limits, means, and variances. Logging occurs each time a signature acquisition is performed or each time a system command is typed in. A printout of the log is available as another output device via the printer when requested by the user.

DAILY UTILIZATION LOG

The daily utilization log (DUL) program is an automated interactive terminal usage accounting feature.

SCALED CURSOR

The scaled cursor program assists in the selection of image areas from magnetic tape. With Landsat data, the user positions the cursor over the area of interest on the CRT display screen. The properly scaled row and column numbers are then exhibited on the graphics display terminal and are used to enter the FULOI program.

IRREGULAR CURSOR

The irregular cursor (IRREG) program allows the user to select an irregularly shaped training field with as many as 29 corners and place it in theme storage for later use.

Data Output

VIDEO FILE INPUT/OUTPUT

The video file input/output (VIDPIP) program allows the user to select any one or as many as five video channels for storage on disk, magnetic tape, or other storage device. Files can be restored or deleted at will. This is a rapid way of storing imagery data for later analysis on the same system.

THEME FILE

The theme file input/output (THEMPIP) program allows the user to select any one or as many as eight theme tracks for storage on disk, magnetic tape, or other storage device. Files can be restored or deleted at will.

TAPE WRITE

The LARSYS tape write and Universal tape write programs write the contents of the refresh memory to magnetic tape in their respective formats.

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ALPHANUMERIC THEME PRINT

The alphanumeric theme print (ANTP) program outputs to the printer/plotter any combination or all of the themes, printing either the entire or just the cursored area of the screen.

DIGITAL THEME PRINT

The digital theme print program outputs one theme to the printer/plotter. Each element of the theme is represented by a square matrix of dots, and the entire screen is output onto continuous rolled or two consecutive sheets of fanfold paper. The desired theme track number is requested, after which one line of text can be entered; this will be output as the title on the printout.

Special Purpose

Special-purpose programs for adjusting input scanner data allow the analyst to apply a shading correction to compensate for irregular illumination on the image. To improve the quality of the image, the analyst also has access to a scanner video averaging program.

Procedure 1

Procedure 1 is a classification hybrid system method that processes dots instead of training fields. It utilizes both the Image 100 and the LACIE System in support of the LACIE CAMS. An Image 100 user can now apply Procedure 1 to LACIE segments. This integrated system contains the following programs.

IMAGE DISPLAY

The image display program allows the analyst to display LACIE imagery in several ways for study using Procedure 1.

DO/DU FIELDS

The designated other/designated unidentifiable field definition (DO/DU FIELDS) program allows fields which have been excluded from clustering and classification to be defined interactively at the Image 100 console.

SELECT AND DISPLAY DOTS

The select and display dots program allows the analyst to select a subset of all dots in the LACIE segment and display them on the CRT.

SCATTER PLOT

The scatter plot program allows the user to generate scatter plots of any two spectral coordinates, including Kauth greenness and brightness.

DOT LABELING

The single-dot labeling with trajectory plots program allows the analyst to select a single dot, examine its trajectory through spectral space, and label or relabel it by category and type.

CLUSTER LABELING

The automatic cluster labeling program assigns labels to each cluster using labeled dots.

MAP DISPLAY

The cluster and classification map display programs allow the analyst to display individual clusters, all clusters with a common label, and classes.

REPORTS

The reports program produces many detailed reports upon user request.

DATA BASE OPERATIONS

The data base operations program provides for the insertion or extraction of a wide variety of data into or from the data base.

BATCH

The programs for offline updates of the CAMS Image 100 Data Base are maintained on the system disk and are available for execution in the batch mode.

CAMET

The Classification and Mensuration Evaluation and Test (CAMET) programs were developed specifically as a first test of LACIE procedures in the Image 100 system. Although the CAMET programs are no longer needed for their original purpose, some of the following available programs have proven useful.

IRREGULAR CURSOR

The IRREG program, CAMET version, offers all the capabilities of the IRREG program plus the capability of reading vertices from the file and the option of displaying field boundaries only.

N-D SIGNATURE ACQUISITION

The N-D signature acquisition (CNDA2) program determines the multidimensional histogram for an area defined by the cursor, theme track, or alarm. The program uses a binary search procedure within the limits determined by the 1-D signature acquisition program. The cell size (i.e., resolution) and file name are selected by the user from the PRMTR program prior to signature acquisition.

CLUSTER

Cluster (CLUSTR) program forms as many as 20 clusters from the N-D histogram file.

NONPARAMETRIC MAXIMUM LIKELIHOOD CLASSIFICATION	The nonparametric maximum likelihood classification (CLASS) program makes a maximum likelihood decision on the classification vectors occurring in more than one class.
MASKED VIDEO ERASE	The masked video erase (MASKVD) program rewrites refresh memory channels 1 through 4 using theme 1 as a mask.
TEST PATTERNS	The test patterns (TSTPAT) program writes to refresh memory four different intensities in different patterns for each of channels 1, 2, and 3. In addition, it writes the appropriate powers of 2 to channel 5 refresh memory, so that the screen is divided into eight equal sections and each section represents one theme.
GSFC/LACIE TAPE PROCESSING	The GSFC/LACIE tape processing (GODDAR) program processes segment-size files (196 pixels by 117 scan lines) from GSFC/LACIE tapes to merge multiple passes and produce a composite site tape in RSX-11D Files-11 format.
GAIN AND BIAS APPLICATIONS	The gains and biases for GSFC data (TAPREF) program applies gains and biases to any 4 channels or 4 linear combinations of as many as 16 channels from the Files-11 site tape generated by the GODDAR program and writes the resulting vectors to the Image 100 refresh memory.
STATISTICS COMPUTATION	The statistics computation (STAT) program computes the mean vector and covariance matrix for a maximum of eight classes defined by the eight theme tracks. Statistics are computed from data read from an image tape or disk file in the format generated by the GODDAR program. Statistics are computed for all channels on the image file and written to the disk file STAT.DAT for input to the channel selection ordering (SELECT) program.
CHANNEL SELECTION	The SELECT program reads the statistics file prepared by the STAT program and allows the user to select a subset of the channels for classification and to specify *a priori* values for each class. The program then orders the statistics so that the amount of computation to be performed in classification is minimized. The prepared statistical tables are written to disk file TABLES.DAT and to the line printer.

PARAMETRIC MAXIMUM LIKELIHOOD CLASSIFICATION

The parametric maximum likelihood classification (ICLAS) program performs parametric maximum likelihood classification for every pixel in a 196-pixel by 117-scan-line segment-size scene. The image data must be in the format output by the GODDAR program.

RESULTS DISPLAY

The display classification results (DISPLA) program reads the classification results file prepared by the ICLAS program and outputs the results to channel 5 of the refresh memory so that each class can be displayed on individual themes.

CLASSIFICATION SUMMARY

The classification summaries (THEMAR) program computes and prints (on the line printer) classification summaries giving the total pixels on each theme, the probabilities of misclassification for wheat and nonwheat, and the proportion estimates within the provided field. Computations are based on the areas of the eight theme tracks, which must be prepared by the user.

GRID WRITE

The grid write (GRID) program writes a grid on theme 8. The grid begins at line 80, sample 60, on the screen. Horizontal lines are drawn at intervals of 32 lines, and vertical lines are drawn at intervals of 20 samples.

CAMS Accuracy Assessment

The CAMS Accuracy Assessment System is designed to derive ground-truth maps from digitized ground-truth data and to use these maps to assess the accuracy of the CAMS classification and proportion estimates. The system is comprised of the following programs.

DATA TRANSFER

The LACIE data transfer record manager (DTERM) program produces a printed file directory of the LACIE DTERM tape (DTRM).

BENDIX TAPE PROCESSOR

The Bendix tape processor driver (BTMAIN) program reads the digitized field vertices from the Bendix 100 IDS tapes and operates on field vertices and crop codes to produce a subpixel-level ground-truth data tape in Universal format.

DISK FILE BUILD

The five-unit software module (MODULE 2) programs create a disk data file consisting of ground-truth, DTRM, and CCIT data.

REPORT GENERATION

The three-unit software module (MODULE 3) programs create and print the various Accuracy Assessment reports.

FIELD STATISTICS

The field statistics (FIELDSTAT) program provides statistics which describe the signatures of the classes in the raw image data as determined by the ground truth.

SCATTER PLOTS

The classification and mensuration plotting (CAMPLT) program produces scatter plots of green numbers versus brightness on a fixed scale for selected acquisitions.

Batch

The RSX-11D batch processing capability allows the user to submit jobs to a system operator for subsequent processing. Each job contains a series of commands to the system and may contain associated data. Once the job has been submitted, its tasks can be executed without operator intervention unless operation action is specifically requested. Batch processing jobs have the capabilities to:

- Compile a Fortran program.
- Assemble a MACRO-11 program.
- Link programs.
- Execute programs.
- Sort data files.
- Mount and dismount tapes or disks (operator action).
- Issue messages to the operator and (optionally) wait for a response.
- Include in the batch stream the source codes for compiling and assembling a program and the data for processing.
- Perform common utility functions.

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Software Design Specification for Daily Utilization Log (DUL) Program. JSC-10471, NASA/JSC (Houston), Sept. 1977.

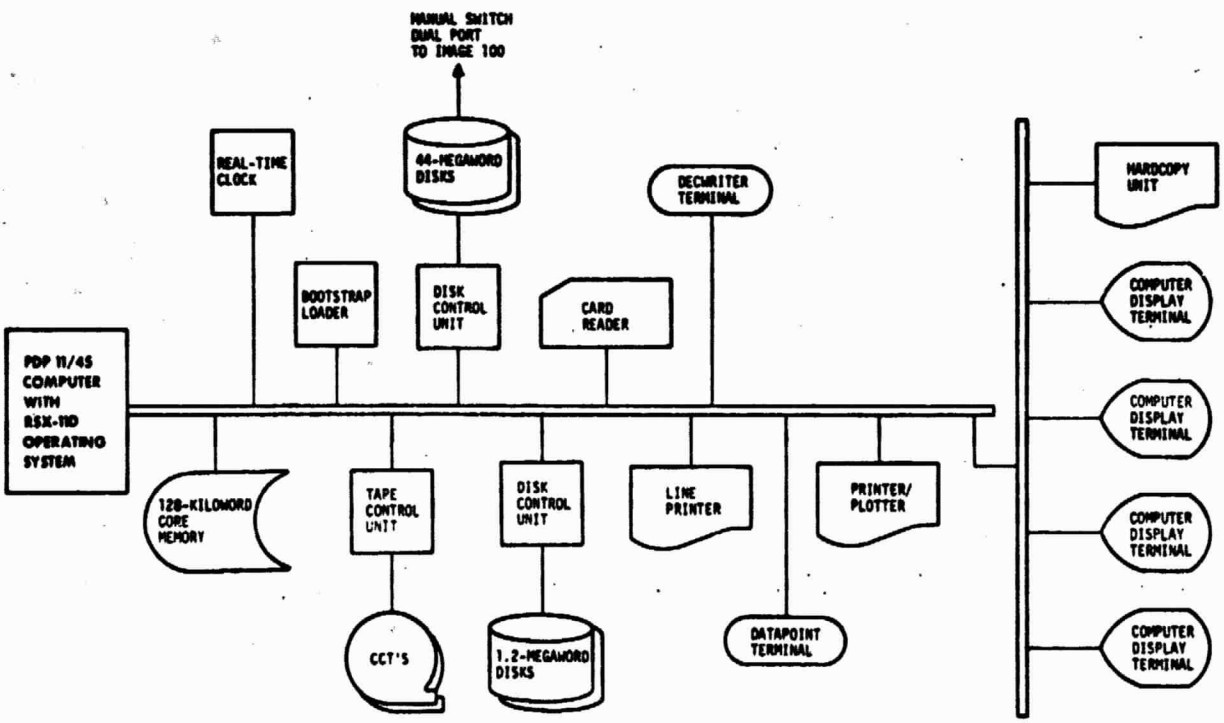
Support Processor

GENERAL

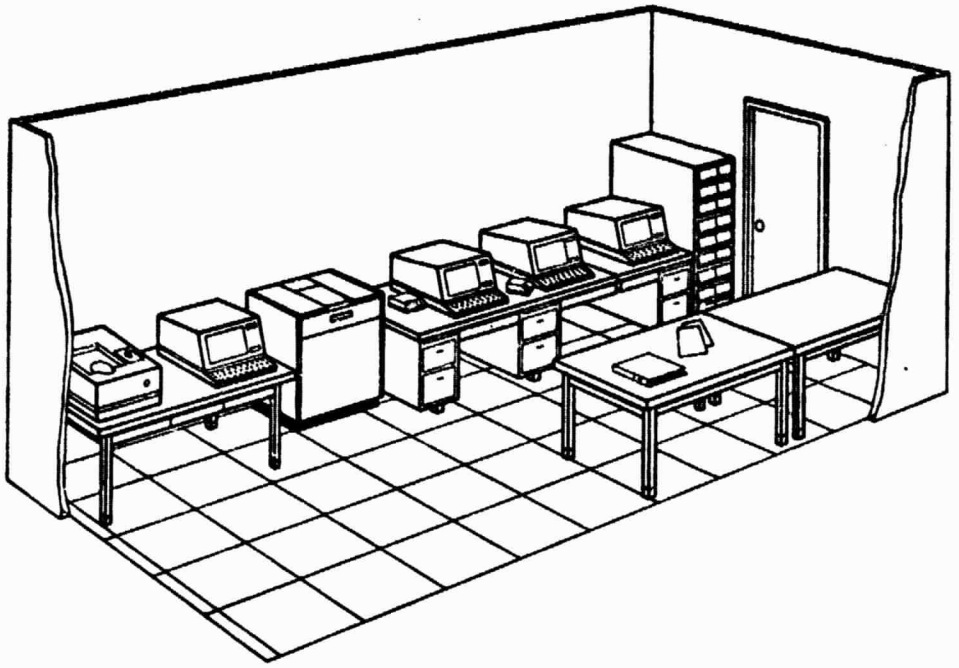
The Support Processor Computing System was originally installed to provide interactive support to the LACIE CAS. Since its installation, additional processing capabilities have been added.

HARDWARE

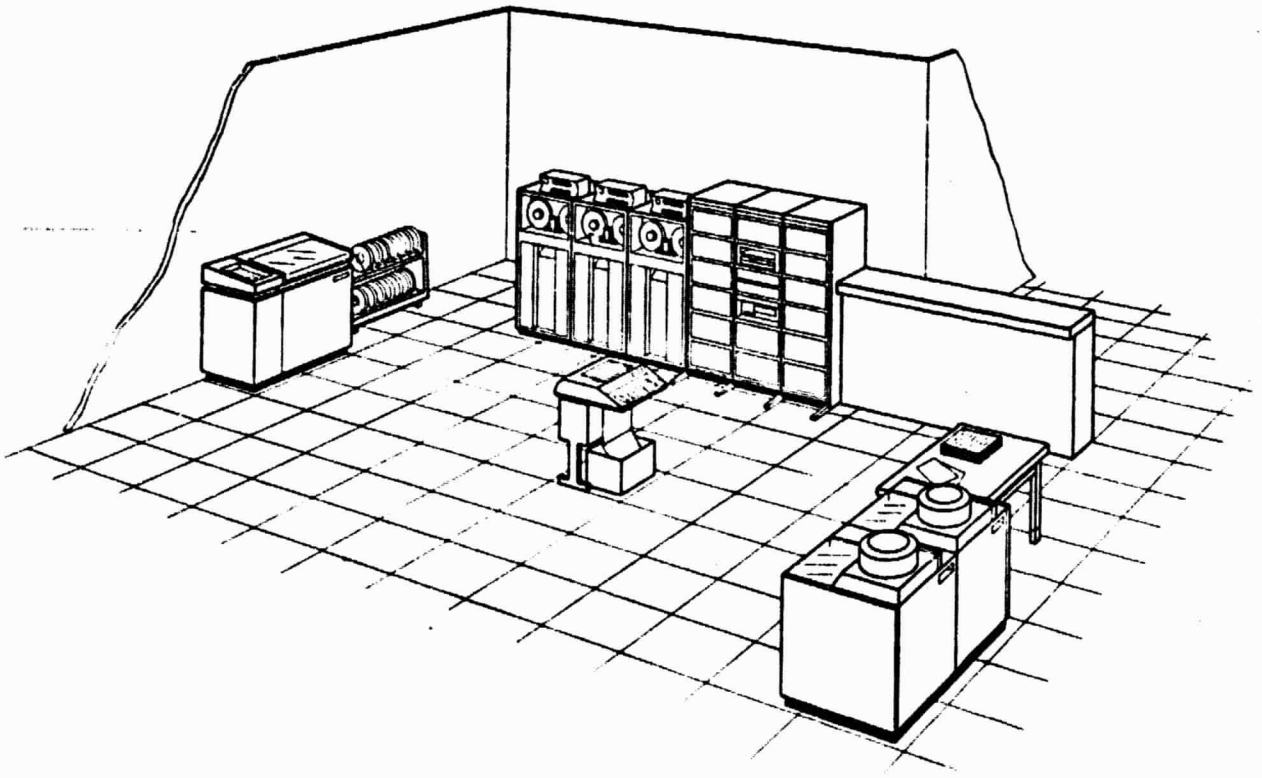
The Support Processor configuration includes a PDP 11/45 computer with 128 kilowords of core memory, one dedicated 44-megaword disk, one 44-megaword shared disk, two magnetic digital tape units, two 1.2-megaword disk units, a video hardcopy unit, and five alphanumeric terminals.



Hardware configuration for Support Processor.



Support Processor remote terminals.



Support Processor PDP 11/45 system.

SOFTWARE

The implementation of the RSX-11D operating system supports a multiuser environment with the following software systems.

LACIE CAS

The LACIE CAS is comprised of three processing functions:

BATCH

- Batch processing
  - Allocation data processing
  - CAMS batch updates
  - Yield Estimation Subsystem (YES) batch updates
  - Data Preprocessing and Transmission Subsystem (DAPTS) batch updates

DATA BASE CHANGE

- Interactive data base change processing
  - YES Data Base update
  - DAPTS Data Base update
  - CAMS Data Base update
  - Dump Data Base Change Report File

DISPLAY, AGGREGATION, AND REPORTING

- Interactive display, aggregation, and report processing
  - Production aggregation at the regional level
  - Area aggregation at the regional level
  - Yield aggregation at the stratum level
  - Pseudoregion area aggregation
  - Pseudoregion production aggregation
  - Total area aggregation at the country level
  - Total production aggregation at the country level
  - Yield aggregation for winter wheat at the country level
  - Yield aggregation for spring wheat at the country level

Data Management

The Regional Information Management System (RIMS) provides generalized data management capability on the PDP 11/45.

Status and Tracking

The LACIE Automatic Status and Tracking System (ASATS), which was implemented under the RIMS, is a management tool which traces the flow of LACIE materials from the collection of data through the various imagery and mensuration stages and finally to the production of valid crop-yield estimates.

Image Library

The Image Library contains various image manipulation routines in support of the Image 100.

Batch

Batch utilities include routines for card output and tape dump.

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Production Film Converter

The PFC is a functional part of the Earth resources LACIE System. The PFC will accept Universal-formatted digital tape inputs. Sources of data input to the PFC include LACIE, Image 100, Skylab and aircraft sensor, calibration, and navigational data. It produces film images on either 70-millimeter or 5-inch black-and-white or color film.

PFC programs are available for processing digital data in Universal format from the following sensors:

- S-192 MSS
- Aircraft 24-channel MSS
- Remote multispectral sensor 14 (RS-14)
- Remote multispectral sensor 18 (RS-18MS)
- Reconofax IV
- Landsat 16-channel MSS (4 channels of data merged)

Using data from the Landsat MSS, the PFC generates common products which support the LACIE segment data and the following LACIE segment imagery.

Product 1 — Procedure 1 color infrared

Product 2 — Procedure 1 enhanced color

Product 3 — Temporal color composite

Product 4 — Procedure 1 4-channel black and white

Product 5 — Procedure 1 single black-and-white screening

Product 6 — Color classification map

Product 7 — 4-channel color (3-channel composite 7 monachrome)

Product 8 — Black-and-white classification map

Product 9 — Color cluster map

Product 10 — Linear combination black and white

Product 11 — Linear combination color

Product 12 — Black-and-white field boundary overlay

Sensor Analysis Laboratory

GENERAL

The Sensor Analysis Laboratory (SAL) was originally designed to provide a single facility for the quick-look evaluation of Airborne Instrumentation Research Project (AIRP) remotely sensed data for the Experiment Systems Division. This involved processing data from functional check flights to determine sensor readiness for mission data acquisition and from laboratory tests supporting sensor development.

Although the SAL continues to support that function, it has also had the responsibility, since October 1977, to generate user data products for Principal Investigators (PI's) of the AIRP. The SAL also supports software development for AIRP sensors and is expected to provide data processing support for tests from Space Shuttle Orbiter Experiments.

The present capability utilizes both general-purpose programs for the analysis of numerous types of sensor data and dedicated programs to support a specific type of data. The emphasis is on providing a flexible configuration to accommodate a wide range of applications.

HARDWARE

The laboratory consists of an offline system, an analog tape-dubbing station, a preprocessor system, and an online system.

Offline

The offline system consists of hardware units capable of producing strip charts, visicorder products, and tape-to-film products. The tape transport (Model FR1900) is used to reproduce the data from the aircraft sensor tapes on the offline system. The time code translators (TCT's) are required to display the Inter-Range Instrumentation Group (IRIG) time from the tapes. One of two decommutation systems, the Electro-Mechanical Research (EMR) or the ARNOLD, is used to decode the bit streams of the various pulse code modulation (PCM) formats. The decommutation systems employ a bit, a frame, and a word synchronizer, as well as digital-to-analog converter outputs. After the data have been decommutated, the required output is determined.

BRUSH RECORDERS

The data signal from the decommutation system's 32 digital-to-analog converter outputs may be patched using the patch panel to one of the three brush recorders for the production of strip charts. Eight parameters, one event mark, and slo-code time may be displayed on a strip chart. Paper speeds from 1 to 200 millimeters per second are available.

VISICORDERS

Visicorder products may be produced for any given channel of data. For visicorder strip charts, the magazine is loaded with the appropriate paper roll. Screening products for the modular multiband scanner (M^2S or MMS) and the NASA multispectral sensor 001 (NS001MS) are generated on this visicorder.

REMOTE FILM RECORDER

The remote film recorder 70 (RFR-70) is a tape-to-film converter used to make screening film products for the M^2S, the RS-18MS, and the NS001MS. One channel, as selected, can be produced as output on 70-millimeter black-and-white film. One-minute timing marks are also incorporated onto the film.

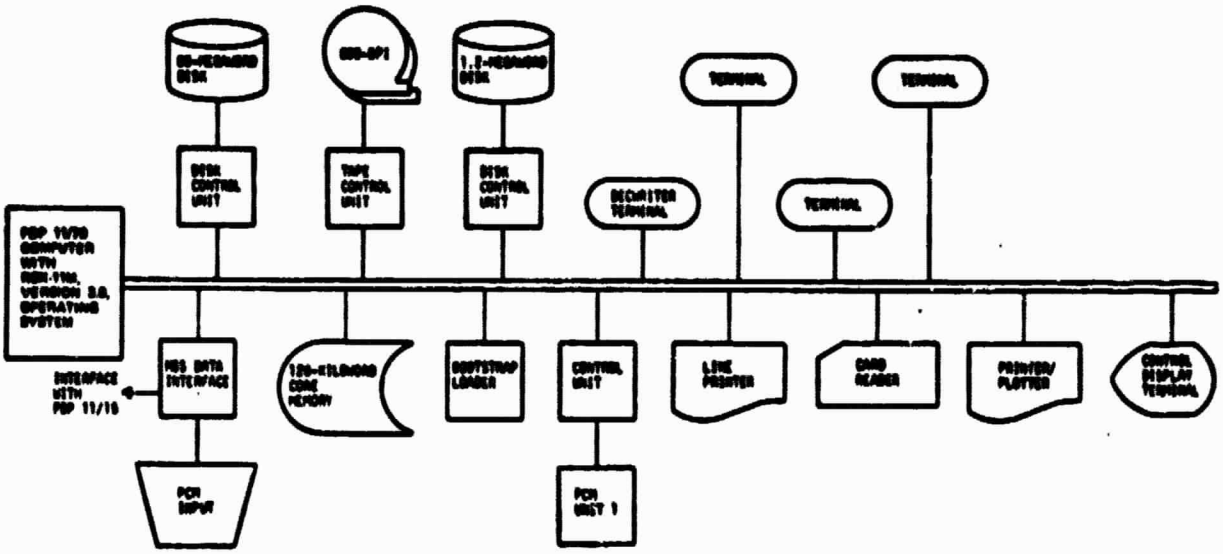
Analog Tape-Dubbing Station

The tape-dubbing station has the hardware necessary to produce copies of original aircraft sensor tapes. Analog tape transports (Models FR1900 and FR2000) and accompanying patch panels and test equipment are used to make copies of these sensor tapes. The FR2000 is used for reproduction, whereas the FR1900 is used for recording.

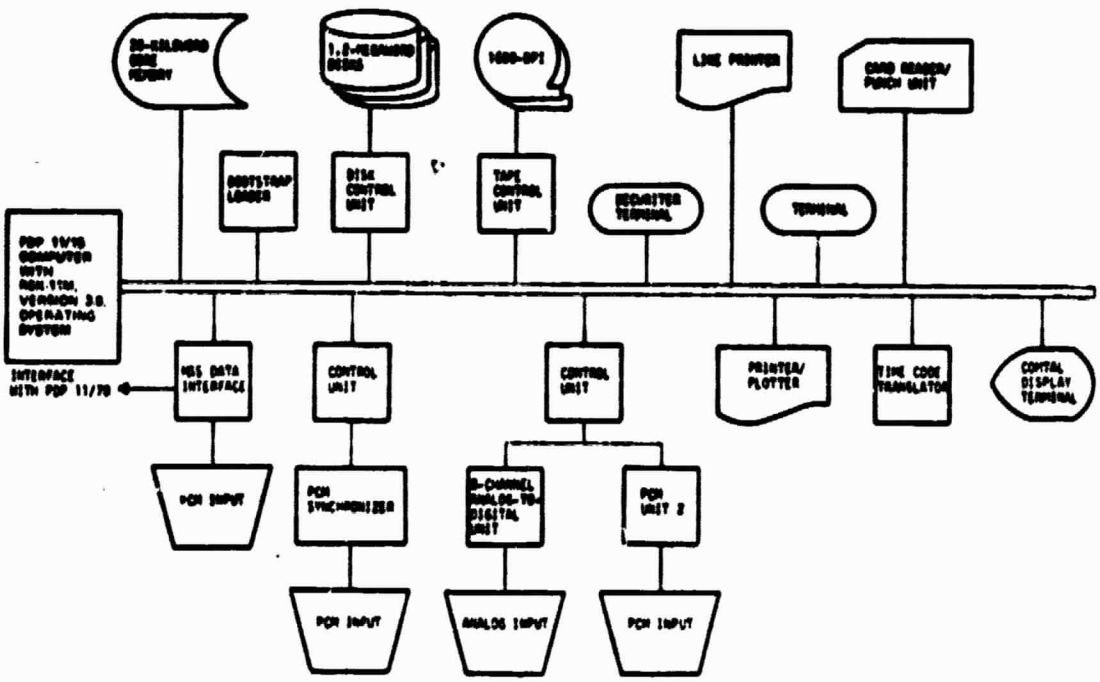
New tapes can be generated, also, if proper signals are available from sensor laboratories via hardlines or using simulated signals. The capability to generate IRIG time is also available.

Online and Preprocessing

The SAL online and preprocessing configurations are shown in the following diagrams.



Hardware configuration for the PDP 11/70 online system for the SAL.



Hardware configuration for the PDP 11/15 preprocessing system for the SAL.

SOFTWARE

The sensor evaluation software utilizes the Resource Sharing Executive, Model 11M (RSX-11M), version 3.0, operating system. The RSX-11M supports MACRO-11 (version 6.03) assembly language and Fortran IV Plus (version 2.5) programming. Numerous utility support programs are also included. Among these are Test Editor, Linker, Peripheral Interchange Program (PIP), Filedump, Assembler (MACRO-11), Fortran Compiler, Online Debugging Technique (ODT), Library, and Indirect Command File capabilities.

The RSX-11M is a multiuser operating system that permits more efficient utilization of system resources. It is a disk-based real-time operating system that provides an environment for the execution of multiple real-time tasks (program images) using a priority-structured, event-driven scheduling mechanism.

The RSX-11M can be generated as either a mapped or an unmapped system, depending on the requirements of the sensor support or the user data products. Unmapped systems support only user-controlled partitions. Mapped systems support both user-controlled and system-controlled partitions. Services which require memory-mapping hardware are provided by the memory management unit (Model KT11).

The following is a summary of the programs which have been developed over the past 4 years. They are used for generating user data products, providing quality control of processed data, performing routine utility tasks, and processing data from now inactive sensors. Close rapport with the sensor engineer, detailed knowledge of the data, and basic understanding of the hardware and software in the SAL have led to the capability to provide a timely and effective product and a high degree of confidence in the results. In each case, numerous diagnostic and verification procedures have been adopted to assure the accuracy and reliability of the processing.

User Data Product Generation

The following computer programs are utilized to generate user data products for the PI's.

The NASA Earth resources (NER) program generates NASA Earth Resources Data Annotation System (NERDAS) guidance and navigation tabulations at one sample per second versus NERDAS time. The NER program can process NERDAS data from either the RB-57F or the C-130 aircraft. [The sensor format is described in the Data Format Control Book (DFCB), JSC-13896, page 4-36.]	NASA EARTH RESOURCES
The NER1 program outputs the same information as NER at 10 samples per second.	NER1
The NERDAS for Alaska Mapping Project (NERA) program outputs the same information as NER except a three-digit line number is in the site number slot and ALASKA is hard coded in the line number slot.	NERA
The uncorrected camera correlation (NCAC) program generates uncorrected camera correlation tabulations from the RB-57F and C-130 aircraft. A maximum of 300 frames may be captured at one time, and a summary total is generated. (The format of the tabulations is described in the DFCB, page 4-34.)	UNCORRECTED CAMERA CORRELATION
The corrected camera correlation (CAMERA) program generates corrected camera correlation tabulations (as in the NCAC program) and a corrected CCT. Products include pertinent camera and film information, including the frame number and scale. Options include file manipulations such as COPY, CHANGE, DISPLAY, DELETE, REPLACE, SKIP, TOP, EXIT, and LIST.	CORRECTED CAMERA CORRELATION
The NERDAS 8 tape (N8T) formatting program generates a raw data intermediate CCT (in counts) of the Barnes precision radiation thermometer 5 (PRT-5) and total air temperature (TAT) sensor data from PCM format 8. NERDAS or IRIG time also may be merged on this tape.	NERDAS 8 TAPE FORMATTING
The PRT-5 program produces a CCT and/or tabulations of PRT-5, TAT, and altitude and ground-speed data in engineering units versus both IRIG and NERDAS time. The program processes data formatted by either the N8T program or its predecessor, PCM format 6 to CCT (F6T).	PRECISION RADIATION THERMOMETER

PRINT PLOT	The print plot (PRTPLT) program produces time history plots of data from the CCT generated by the PRT-5 program. (The format of the plot is described in the DFCB, page 4-11.)
NERDAS 10 FORMATTING	The NERDAS 10 (N10) formatting program generates a raw data CCT of the multifrequency microwave radiometer (MFMR) data from PCM format 10 merged with NERDAS and IRIG time.
MULTIFREQUENCY MICROWAVE RADIOMETER	The MFMR program processes the N10 CCT to produce corrected MFMR data versus IRIG time with pitch and roll output on a CCT and/or line printer. An option is available to provide tabulations from all bands or housekeeping tabulations from a selected band. Averaging time is also optional.
NERDAS 11 FORMATTING	The NERDAS 11 (N11) formatting program generates a raw data CCT of the PMIS data from PCM format 11 merged with NERDAS and IRIG time. The CCT format is the same as N10 except that PMIS data are substituted for MFMR data.
PMIS	The PMIS program produces PMIS data tabulations and a plot file from the N11 CCT.
PMIS PLOT	The PMIS plot (PMSPLT) program plots the corrected PMIS data from the plot file generated by program PMIS. The start and stop times, as well as the averaging time, are selectable.
SENSOR TAPE TO CCT	The sensor tape to CCT (S2C) reformatting program generates a LARSYS-III-formatted CCT of the modular M^2S data acquired since March 1978. This unmapped dedicated program will process from 1 to 11 channels simultaneously with a selectable line start/stop of either Greenwich mean time (GMT) or scan-line count. Flight-line information is input via terminal, and a status summary and/or error check are output after each run. This program may be used also to process other sensor data. (The format of the M^2S LARSYS-III-formatted CCT is described in the DFCB, page 5-21.)
LARSYS III TO UNIVERSAL	The LARSYS III to Universal format (L3UF) program converts a LARSYS-III-formatted CCT of M^2S or RS-18MS data to a Universal-formatted CCT. The processing status summary and READ/WRITE parity error status are output after each data file. (The format of the M^2S Universal CCT is described in the DFCB, page 5-4.)

SENSOR TAPE TO CCT

The sensor tape to CCT (STC) program, the initial version of the S2C reformatting program, generates a LARSYS-III-formated CCT of the M^2S data acquired prior to March 1978. The program has the same capabilities as the S2C program, except error checks are not as extensive. This program may also be used to process other sensor data.

SENSOR NS001MS TO CCT

The sensor NS001MS to CCT (SNC) program generates a LARSYS-III-formatted CCT of the thematic mapper simulator NS001MS data. SNC utilizes the unmapped operating system and thus requires a dedicated computer facility. The program will process from one to eight channels simultaneously with a selectable line start/stop of either GMT or scan-line count. Flight-line information is input via the system terminal, and a status summary and/or error check are output after each run. (The format of the NS001MS LARSYS-III-formatted CCT is described in the DFCB, page 5-68.)

LARSYS NS001MS TO UNIVERSAL

The LARSYS NS001MS to Universal (LNU) program converts a LARSYS-III-formatted CCT of the NS001MS data to a Universal-formatted CCT. A processing status summary, along with the READ/WRITE parity error status, is output after each data file. (The NS001MS Universal format it described in the DFCB, page 5-51.)

Programs for Quality Control

DUMP OF LARSYS-FORMATTED DATA

The dump of LARSYS-formatted data (DLARS) program provides a decimal dump of any LARSYS-III-formatted CCT. DLARS takes integer, real, and alphanumeric data, converts them to American Standard Code for Information Interchange (ASCII), and then dumps the data in decimal form. DLARS is used to verify CCT's generated by the STC, S2C, and SNC programs.

DUMP OF UNIVERSAL-FORMATTED DATA

The dump of Universal-formatted data (DUNIV) program provides a decimal dump of any Universal-formatted CCT. DUNIV takes binary-coded decimal (BCD) and EBCDIC data, converts them to ASCII, and then dumps the data in decimal form. DUNIV is used to verify CCT's generated by the L3UF and LNU programs.

IMAGE ANALOG TAPE SCREENING

The image analog tape screening (IMAGE) program displays imagery data from the M^2S, RS-18MS, or NS001MS directly from the aircraft sensor tape on the COMTAL Image Display System. The display is 512 by 512 pixels from the serial PCM input. Selection is made from interleaved or noninterleaved data formats (every word or every other word). The starting pixel is determined by the operator. The next 512 elements are displayed from left to right on the screen. Data channel assignments are made by the operator to one of the four image channels (0 through 3). Processing is continuous or may be stopped after a full screen (512 lines).

LINE START/STOP FROM NERDAS

The NER start/stop (NERST) program provides the line number, latitude, longitude, and ground speed from the NERDAS data only at the times of line start and line stop. NERDAS data are obtained directly from the aircraft sensor tape and are decommutated prior to NERST processing. NERST may be used to verify products generated by the NER, NER1, NERA, NCAC, or CAMERA program.

PMIS COMTAL SCREENING

The PMIS COMTAL screening (PCS) program displays PMIS data directly from the aircraft tape onto the COMTAL Image Display System for screening. Both horizontal and vertical polarizations are displayed simultaneously for each of the 45 beam positions. Display may be normal, pseudocolor, or functional memory processing. Blank lines also may be inserted.

UNIVERSAL FORMAT SCREENING

The Universal format screening (UFS) program displays data from the M^2S, RS-18MS, NS001MS, or solidstate array spectroradiometer (SAS) CCT's in either the LARSYS III or Universal format onto the COMTAL Image Display System for screening. UFS is the primary quality control screening program for L3UF and LNU to subjectively verify M^2S, RS-18MS, and NS001MS output products.

UNIVERSAL DECIMAL DUMP

The Universal decimal dump (UNIVRS) program provides a decimal dump of PRT-5 and/or TAT data from a Universal-formatted CCT. UNIVRS takes positive binary integers, converts them to ASCII, and then dumps the data in decimal form. UNIVRS is used to verify CCT's generated by the PRT-5 program.

MAGNETIC TAPE INPUT/OUTPUT

The magnetic tape input/output (TAPIO) utility program is used to manipulate the digital tape drives. This Fortran-compatible subroutine handles data transfer through the executive via an IBM QIO (input/output) function. It provides tape attachment, release, rewind, read, write, and status reporting capabilities and allows direct access of recorded data on CCT to be placed into a buffered area directly in the user program (instead of having to use a common block). Variable densities and track support are available; however, the current hardware limitation is 9-track, 800-bpi, tape drives.

COPY

The COPY program makes a copy of any number of files from one digital tape to another. COPY will permit tapes up to 10 kilobytes per record to be duplicated under the RSX-11M operating system. The copy is in 9-track, 800-bpi, now return to zero inverted (NRZI) format. No corrections, deletions, or insertions are available with this program.

COLOR STUDY

The color study (CSY) program provides the capability to manipulate remotely from the terminal the colors desired on images displayed on the COMTAL Image Display System. Since multiple passes are available to assign different data channels to different image channels, a false-color presentation can be obtained by this method. While screening, a pseudocolor or functional memory may be applied to the data. Color slicing and/or rescaling therefore can be dynamically applied to the data.

CARD TO TAPE

The card-to-tape (CTOTP) program reads cards from the card reader and writes the card image on a CCT. The cards in IBM Q29 format are processed in data records from 1 to 80 characters in length. The CCT is 9-track, 800-bpi, NRZI format. A dump of the CCT is also available.

DATUM

The DATUM program checks the computer/EMR controller interface to verify that valid time is being received and processed whenever IRIG time is required to be merged with sensor data to produce an output product. DATUM provides a quick-look product via terminal and/or terminal printer to verify proper translation and processing of IRIG time.

DUMP IMAGE

The dump image (DIMAGE) screening program provides the capability to dump the CONTAL Image Display System refresh memory contents for images 1, 2, and 3 to a nine-track CCT. This preserves an image that has been displayed from a sensor tape. The program also permits the CCT to be restored to the disk refresh memory by operator control.

DATA REQUEST

The data request (DR) program checks the computer/ARNOLD interface to verify that valid data are being received. The program provides the capability to troubleshoot the configuration by monitoring the DATA.REQUEST line via scope presentation. This is a diagnostic-type program.

EMR SETUP

The EMR setup (EMRSET) program provides the capability to initialize the EMR remotely to decommutate data from various sensors and eliminates having to set the frame synchronizers manually. This simplifies the running of the N8T, N10, and N11 programs. EMRSET will automatically set all required switches on the EMR 2731 PCM frame synchronizer and/or the EMR 2736 PCM subframe synchronizer for proper decommutation either online or offline when one of the following setups is used:

SETUP 1 — Auxiliary Data Annotation System (ADAS)

SETUP 2 — NERDAS

SETUP 3 — Environmental sensors (NASA RB-57 aircraft)

SETUP 4 — PCM format 4, laser profiler

SETUP 5 — M^2S

SETUP 6 — PCM format 6, PRT-5, PMIS, and MFMR

SETUP 7 — Texas A&M 13.3-GHz scatterometer preprocessor

SETUP 8 — PCM format 8, PRT-5 and TAT

SETUP 9 — Langley Military Air Transport Service (MATS) PCM (NASA RB-57 aircraft)

SETUP 10 — Field Spectrometer System (FSS) PCM

EMR SIMULATOR

The EMR simulator (EMRSIM) program sets up the EMR 2793 stored program simulator remotely to generate simulated data in any of the imagery or nonimagery data formats listed below for each of the designated sensors. EMRSIM is similar to EMRSET except that this program is normally used for acceptance testing, troubleshooting, or quality control for these sensors.

Format	Sensor
MSS.SIM	Multispectral Scanner
ADAS.SIM	Auxiliary Data Annotation System
PMIS.SIM	Passive Microwave Imaging System
RS18.SIM	Remote multispectral sensor 18
NERDAS.SIM	NASA Earth Resources Data Annotation System
TEST.SIM	Specialized
SOBP.SIM	Scatterometer on-board (SOB) processor
SASII.SIM	Solidstate array spectroradiometer
BUG.SIM	Specialized
M^2S.SIM	Modular multiband scanner
ANT.SIM	Specialized

MASTER MEASUREMENTS LIST

The master measurements list (MMLJ) program reads and tabulates a Space Shuttle master measurements list (MML) and outputs it to CCT. The tape is formatted in 6360 bytes per record (10 measurements per record). Processing consists of unpacking the desired parameters, converting them from EBCDIC to ASCII, and tabulating the results via the line printer. Options include selecting measurements or a particular series of measurements and the characteristics of each. MMLA was the initial version of this program.

GENERAL-PURPOSE PLOT

The PLOT program provides the capability to plot data for which no dedicated plot program exists. A plotting file called DATAMX.BIN must be created prior to running this program. This program is utilized by the noise equivalance delta X (NEDX), computation and statistical analysis (CASA), histogram (HISTO), and SOB programs.

POOR QUALITY

DATA MATRIX	The data matrix (DATAMX) program allows for the establishment and creation of a disk data file. It permits the opening, closing, reading, and writing of a data set utilizing the executive directives "GET" and "PUT." The default device is DB0: and may be altered by changing the source code. The file name DATAMX.BIN may be edited to provide a more appropriate designation by the user.
PULSE PER REVOLUTION	The pulse per revolution (PPR) program is a general-purpose scan-rate stability program. The scanners generate a PPR signal, and this signal is input to the special PPR interface logic box. Tabulations of the delta times between pulses, absolute period times in microseconds, and the maximum and minimum delta times are provided. The operator provides annotation, clock rate selection, and the number of pulses to be analyzed.
TAPE DUMP	The tape dump 3 (TDM3) program provides an octal dump of a CCT and converts all identifiable ASCII characters. TDM3 may be used to dump any CCT, regardless of the type of byte encoding. A header record is included to indicate file number, record number, and bytes per record. There are 16 bytes per line, and each line is numbered in both octal and decimal. Bytes or words not in ASCII format must be converted manually.
TIME EDIT	The time edit (TEDIT) program dumps the header and time from intermediate CCT's to verify the validity of time. TEDIT is used to validate IRIG or NERDAS time on CCT's generated by the N8T, N10, and N11 programs. This dump is normally used for troubleshooting purposes.
WRITE EOF	The write end-of-file 0 (WEOF0) program writes an end-of-file (EOF) on the CCT located on digital tape unit 0. WEOF0 is an editing program utilized when one or more EOF's are required on a CCT generated by the L3UF or LNU program. This prevents having to remake the output product CCT when EOF's are missing.

FLOATING-POINT PROCESSOR

The floating-point processor (FPP) program is a general-purpose utility routine with many modules for manipulating data. It performs arithmetic and conversion functions on variables supplied by the user. Integer and floating-point values are supported with conversion to and from ASCII as the standard character set. This software was designed to make effective use of the FPP hardware. Software interface capability is maintained with previous programs to accomplish calculations.

PHILCO HOUSTON OPERATIONS

The Philco Houston Operations (PHO) program permits the setup and initialization of the multitrack PCM interface designed by Ford Aerospace and Communications Corporation (formerly PHO). Transfers of data are buffered automatically into the specified user area. Operation of this software requires the use of the unmapped operating system because interrupts are to be handled and only 16 bits are mapped for storage addresses. Commands to and from the device are made directly from the program and do not go through the executive operating system software. PHO is an integral part of the STC, S2C, and SNC programs that generate user data products. The capability to receive IRIG time from the PHO time code reader is also provided.

PCM

The PCM program handles setup and initialization of either the EMR or the ARNOLD PCM decommutation units. Block transfers of information are made to the common block (ICOM) area in memory in each case. Tests are made for block completion in terms of using the priority interrupt structure for the EMR. The ARNOLD data are interfaced with a direct memory access (DR11-B) user interface, and checks on its completion are functions of the ready bit. Any program requiring the EMR or ARNOLD will utilize the module.

EBCDIC TO ASCII

The EBCDIC to ASCII (EBAS) program provides the capability to convert to and from ASCII and EBCDIC character strings. This is a general-purpose utility subroutine which normally will be an integral part of another program.

NTRAN

The NTRAN program is a general-purpose Fortran-compatible utility routine which permits users to access digital tapes with a minimum of effort. The functions permitted are reading, writing,

rewinding, writing EOF's, positioning within a file, and closing all input/output functions for the tape.

SCIENTIFIC SUBROUTINE LIBRARY

The Scientific Subroutine Library (SSLIB) program consists of 120 Fortran-callable single-precision subroutines covering a wide variety of statistical and mathematical operations. SSLIB, along with demonstration programs and input data files showing how to use the various routines, resides on the system device under user identification code [UIC(100,3)]. Subroutines in this library may be linked into a program at task-build time by using the following statement:

```
PROG:  TBK PROG/FP = PROG/CC,(100,3)SSLIB.OLD/LB
```

The subroutines and demonstration programs are described more fully in document DEC-11-SSPMA-A-D, Scientific Subroutines Package Reference Manual. Only RSX-11M file-handling statements were added to the test programs.

Research and Development Programs

HISTO

The HISTO program is a general-purpose program which provides expanded capability for histogramming where each count value is limited to 32 767 occurrences. Data input to the program may be selected using one of the PCM decommutation interfaces. The terminal operator inputs an annotation message, the selected PCM system, the start work number, the delta element (word), and the number of lines (frames). The output products are listed below:

- Histogram tabulation
- Serial correlation coefficient calculation
- Peak relative change in frequency coefficient
- Percentage of points at saturation
- Mean and standard deviation calculations
- Histogram plot

The CASA program provides the following products: CASA

- Raw data tabulations in counts
- Mean and standard deviation calculations with maximum and minimum values
- Histogram tabulation
- Scan-line plots
- Histogram plots

Data are selected for input to the program using one of the PCM interfaces. The operator options include an annotation message, PCM system select, start element (word), delta element (word), and number of lines (frames). Calculations are made either for each element in every frame or for every element in every frame. Processing is limited to 14 000 data points. Processing is done in one or two phases, depending on whether a plot is requested.

The NEDX program calculates signal-to-noise ratios and produces histogram tabulations on the calibration sources of the M^2S, RS-18MS, and NS001MS. Sensor data are input using one of the PCM interfaces. Processing is in one or two phases. The calibration sources are selected automatically by the program, depending upon operator response as to sensor type and the choice of visible or thermal reference data. The search scan count is used optionally by the operator to select the area to be used. Three hundred scans are used as the default condition. A noise equivalence delta radiance (NEDR) or NER calculation is performed, depending upon the constant that is input (radiance or rho equivalent). The units are degrees if the datum is a thermal channel. Signal-to-noise calculations are substituted if the constant used is 1.0. The standard deviation, mean, and maximum and minimum values are listed for each calibration source parameter. Histogram tabulations of both calibration sources are provided also. A plot of the histogram is available on the Phase 2 option. NEDX

M^2S HOUSEKEEPING	The M^2S housekeeping (M2SH) program provides the capability to tabulate M^2S housekeeping data directly from the aircraft sensor tape. The tabulations include time, scan-line count, calibration source temperatures, and blackbody temperatures.
SOB	The SOB program processes the 13.3-GHz SOBP analog tape for tabulations and plot file. The SOB program tabulates sigma zero values in decibels versus look angle for each data scan or frame, along with aircraft ground speed, roll, pitch, drift, radar altitude, heading, and IRIG or NERDAS time. The biphase level (Bi-ϕ-L) PCM data similar to the NERDAS format must be merged with IRIG time prior to SOB processing. Operator annotation and scan-line start/stop selection also are required prior to processing.
SOB PLOT	The SOB plot (SOBPLT) program performs special calculations on the files generated by the SOB program. SOBPLT has the capability to take the decibel values, convert them to linear values, calculate an average per selectable scans, and then reconvert back to decibels prior to final plotting. The averaged sigma zero values are then plotted versus the 10 look angles of theta. A summary table also is generated which specifies the start scan line, averaged scan, theta angle, and its associated averaged sigma zero value.
SAS	The SAS program provides raw or averaged tabulations of the SAS data directly from the aircraft sensor tape. SAS data are input via the ARNOLD PCM interface. The operator options include an annotation message, selectable line start/stop time, reprocessing, and selection of the raw data or mean and standard deviation tabulations.
SAS IMAGE	The SAS image (SASIMG) program displays SAS data directly from the aircraft sensor tape onto the COMTAL Image Display System for screening. Operator options include channel select, start/stop pixel, number of scans, S-compression, and Y-zoom. A special color lookup table is available for SAS screening.

SAS TO LARSYS CCT

The SAS to LARSYS CCT (SLC) program reads the SAS data from the sensor tape and generates a LARSYS-III-formatted CCT. This unmapped dedicated program will process from 1 to 21 channels simultaneously with selectable start/stop time. Flight-line information is input on the terminal, and a status summary and/or error check are output after each data file.

SAS LARSYS III

The SAS LARSYS III (SASL3) program reads the SAS data from a LARSYS-III-formatted CCT and generates a Universal-formatted CCT. The processing status summary, along with the READ/WRITE parity error status, is output after each data file. SASL3 utilizes the transfer function coefficients generated by the SAS version 2 (SASV2) program to provide corrected SAS data.

SAS VERSION 2

The SASV2 program utilizes the orthogonal least squares method to generate the spectral radiance transfer function coefficients required to produce corrected SAS data. A second-order fit is now being used for the 21 detector channels. SASV2 requires the CCT generated by the SASL3 as input. It processes up to 10 CCT files at a time and computes the mean and/or standard deviation for each. Two other programs called BUILD and SAS plot (SASPLT) provide the option to plot three types of transfer function curves.

SCATTEROMETER

The scatterometer (SCAT) program is a dedicated series of digital spectral analysis programs developed to process sensor data from the 13.3-, 4.75-, 1.6-, and 0.4-GHz scatterometers. The scatterometer data consist of analog signals recorded on frequency modulation (FM) wideband group I electronics and must be digitized before processing. The scatterometers are digitized using two 12-bit analog-to-digital converters that also require merging of either ADAS or NERDAS data. Processing is accomplished by using a fast Fourier transform and digital filters to generate the required 10 look angles, calibration signals, and noise level. The objective of the programs is to obtain a measure

of the radar backscatter or cross-section area; i.e., sigma zero. Output tabulations consist of the following:

- Selected NERDAS parameters
- Time history of power and calibration in decibels versus NERDAS time
- Calibration data files
- Corrected and uncorrected sigma-zero measurements versus look angles

ENVIRONMENTAL HOUSEKEEPING FOR RS-18MS

The environmental housekeeping for RS-18MS (ENV18A) program processes the 12 RS-18MS pallet temperatures encoded in the UPS1 PCM format. These RS-18MS ancillary data are decommutated, converted to engineering units, and tabulated by ENV18A. Options include operator annotation and selectable line start/stop time.

ENVIRONMENTAL HOUSEKEEPING FOR CAMERA SYSTEMS

The environmental housekeeping for camera systems (ENVCMA) program processes the camera pallet housekeeping parameters encoded on the Universal Pallet System (UPS1) PCM format. The camera pallet has 1 pressure and 12 temperature measures. These camera pallet system ancillary data are decommutated, converted to engineering units, and tabulated by ENVCMA. Options include operator annotation and selectable line start/stop time.

APQ

The APQ program processes the APQ-102 side-looking radar ancillary data encoded on the UPS1 PCM format. The APQ-102 housekeeping information consists of transmitter power, 2 video channels, gain, and 10 horizontal/vertical automatic gain control (AGC) measurements. The APQ-102 housekeeping data are decommutated, converted to engineering units, and tabulated by APQ. The APQ-102 pallet temperatures are processed by the APQ temperature (APQTEMP) program.

APQTEMP

The APQTEMP program, along with APQ, processes the APQ-102 ancillary data encoded on the UPS1 PCM format. The APQ-102 has 12 pallet temperatures. These temperatures are decommutated, converted to engineering units, and tabulated by APQTEMP. Options include operator annotation and selectable line start/stop time.

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Cartographic Technology Laboratory

The Cartographic Technology Laboratory (CTL) has extensive capabilities to research, analyze, and process a wide range of Earth resources data. It has two areas — one containing geometric analysis and processing equipment and one for map compilation and production.

GEOMETRIC ANALYSIS AND PROCESSING CAPABILITIES

General

Because of the flexibility of the CTL, almost any geometrically oriented problem can be considered. The following equipment is used by this laboratory to aid in analyzing geometric problems.

Hardware

WANG 720B AND HEWLETT-PACKARD 9100B CALCULATORS

The Wang 720B and the Hewlett-Packard 9100B (HP9100B) are self-contained programmable electronic calculators that can accept taped programs. The outputs are numerical and visual displays and hardcopy printouts of programmed data.

GERBER 1275 GRAPHIC DISPLAY SYSTEM

The Gerber 1275 Graphic Display System is an automated drafting system with two major components: (1) a large flatbed drafting table which supports an electrically powered traveling bridge that carries an electronically controlled plotting head over a useful plotting area of 60 by 144 inches and (2) a control cabinet containing an electronic computer with an 8-kiloword memory and an input/output teletypewriter and magnetic tape reader. Input data normally are entered from magnetic tapes especially formatted for the Gerber plotter on an offline electronic computer. X- and Y-coordinates are given in inches. Output normally consists of lines either drafted in ink on paper or film or exposed on light-sensitive photographic film. This system has the following major capabilities:

- Plotting accuracy of 5 mils
- Plotting speed to 500 inches per minute

- Manual scale-changing capability from 0.00001 to 999.99999.
- Offsetting of locations from 0 to ±999.999 inches.

BENDIX 100 IDS

The Bendix 100 IDS consists of the following three major components: (1) a 42- by 60-inch light table, a free-moving cursor with control buttons, and an electronic Datagrid digitizer having an accuracy of 0.005 inch; (2) a Nova 1220 electronic computer with 32-kiloword core storage, magnetic storage disks, Fortran IV software, and magnetic tape station; and (3) CRT terminals with teletype keyboards and an electrostatic image duplicator. The Nova computer is programmed to produce magnetic tapes for use on the Gerber 1275 plotter, including a wide variety of preprogrammed letters, numbers, and symbols. The computer also can be programmed for computation work, such as transforming map projections. The Bendix 100 IDS involves three basic steps: (1) digitizing the graphics, (2) proofreading and editing results on the CRT or teletype display, and (3) producing a magnetic tape for reproduction on the Gerber plotter at any desired scale or for input to another system.

RSS-400 GRAPHIC QUANTIZER

The RSS-400 graphic quantizer is an example of the application of integrated circuitry for converting graphics to digital form. The 48- by 72-inch table will accommodate maps, graphs, strip charts, and design drawings. Any point or line on the graph can be digitally scaled and recorded. Measurements in the X- and Y-directions and areas can be recorded. Any graph can be input for measurement or calculation of the enclosed area. Visual digital data and punched cards of the readings are output. The printout shows the measurement of the X-coordinate, followed by the measurement of the Y-coordinate. This machine is presently on loan to the Baylor Medical Center in Houston, Texas.

H. DELL FOSTER DIGITIZER

The H. Dell Foster digitizer is an automated mensuration system with three major components: (1) a glass-topped, back-lighted, drafting table which supports a traveling bridge that carries a manually operated cursor and electric X- and Y-coordinate distance sensors; (2) an electronic digitizer; and (3) a teletype printer with punched paper tape output. The X- and Y-coordinate distance sensors on the traveling bridge measure with an accuracy of 0.001 inch. Scale factors may be manually introduced (from 0.0001 to 9.9999) so that the measurements are converted automatically into any convenient units of area or distance. JSC has computer equipment that will use the punched paper tape to produce punched cards.

MANN COMPARATOR, TYPE 1210

The Mann comparator, type 1210, is a precision screw instrument designed specifically for measuring X- and Y-coordinates on photographic materials to an accuracy of ±0.001 millimeter. This high-quality instrument outputs formatted data (such as X- and Y-coordinates and point identifications) through a digitizer (data logger) onto punched cards for use in various computer programs. This instrument is best suited for performing accurate mensuration on photographic film or glass plates, regardless of the imagery source. A Zoom viewing system with interchangeable eyepieces provides 5X to 20X magnification. This instrument has a 9- by 18-inch measuring format. Computer programs permit reconstruction of even larger photographic formats.

BAUSCH & LOMB MULTISCALE STEREO POINT MARKER

The multiscale stereo point marker is a device for stereoscopically transferring conjugate points from one photograph to another. A continuous Zoom viewing system on this instrument allows conjugate images to be matched using photography of widely varying scales (from approximately 2X to 48X). Points are burned into the emulsion by a thermal die to provide a permanent unambiguous record of the point. The diameter at the die mark is approximately 40 micrometers.

ZEISS SNAP POINT MARKER	The snap point marker is used with a mirror stereoscope to select visually and mark control points manually on aerial photographs.
WILD B-8 AVIOGRAPH STEREOPLOTTER	The aviograph stereoplotter is a general-purpose photogrammetric instrument for accomplishing stereoscopic measurements from stereopairs of approximately vertical photographs (less than 5° tilt). The instrument is equipped with a 2X-to-5X enlarging or 5X-to-2X reducing pantograph. Inputs consist of photographic transparencies (glass plates or film having formats up to 23 by 23 centimeters) acquired with wide- or superwide-angle cameras. It is most suitable for producing medium- to large-scale maps (1:20 000 or larger).
WILD PUG-3 POINT TRANSFER DEVICE	The Wild PUG-3 stereoscopic point transfer device is used for transferring conjugate points from one overlapping photograph to another. The device drills a 60-micrometer-diameter hole in the emulsion of film or glass plate to provide a permanent, unambiguous record of the point. Point transfer is restricted to photographic transparencies of approximately the same scale.
ANALYTICAL STEREOPLOTTER	The analytical stereoplotter (AS-11B1) is a stereophotogrammetric system using a programmable digital computer for real-time stereomodel computations and electromechanical control of a high-precision stereocomparator. Input formats to this system are limited to 9 by 18 inches and normally consist of stereopairs, positional information to reference these photographs to a surface, and data to compensate for non-projective effects (e.g., curvature, atmospheric refraction, lens distortion, and image motion compensation). The outputs include profile, contour, and planimetric plots; ground and model coordinates (three dimensional); photograph coordinates; and orientation parameters of the photographs. Digital data are output via paper tape, magnetic tape, and teletype printout. Various types of imagery have been reduced using

this system. Products from the following equipment may be processed: conventional aerial cameras (metric cameras of various focal lengths), the Apollo 70-millimeter Hasselblad (nonmetric cameras of various focal lengths), 16-millimeter movie cameras, Wild stereometric cameras, and the scanning electron microscope (SEM).

GIGA-ZEISS ORTHOPROJECTOR

The Giga-Zeiss orthoprojector is a projection-type instrument used for the production of orthophotographs (photomaps).. The instrument uses profile (cross-section) data generated by the AS-11B1 to accomplish a strip-by-strip rectification of aerial photographs (transforming central perspective photographs into parallel projection images). Both color and black-and-white orthophotographs may be produced using this instrument. Photography acquired with cameras having focal lengths of 6, 8-1/4, and 12 inches may be plotted directly with the projecting cameras presently available. Other focal lengths may be accommodated through the use of photographic techniques, providing a wide selection of final orthophotograph (photomap) scales. This instrument also possesses the capability to produce a dropped-line contour chart giving direct hypsographic information on the terrain being reproduced as an orthophotograph (photomap). The Giga-Zeiss orthoprojector can accommodate photographic formats as large as 9-1/2 by 9-1/2 inches and accepts either film or glass plates.

WILD CAMERA GONIOMETER

The Wild camera goniometer is a 300-pound optical instrument used to calibrate survey cameras (i.e., to determine the principal point of the camera's focal plane and the effective focal length of its lens). This device consists of a frame that supports the observing telescope, a collimated light source, and an intermediate cylindrical frame that contains the camera body. The goniometer is used to observe a calibrated reseau grid (glass plate) mounted in the camera's focal plane.

Software

WANG PROGRAMS

The Wang calculator has programs available that will convert geographics to Universal Transverse Mercator, Lambert, and state plane coordinates. Other programs include data adjustment, resection (computation of spatial orientation for a specified aerial photograph), image blur plotting for panoramic or frame camera images, and computation of lens distortion curve coefficients.

HP9100B PROGRAMS

The HP9100B calculator has programs available that will convert Universal Transverse Mercator to geographic coordinates, local coordinates to geographic coordinates, and geographic to local coordinates and that will compute the lunar slant range and surface distances of images and lens distortion curve coefficients (less than eight distortion coefficients).

BENDIX 100 IDS PROGRAMS

The basic Bendix 100 IDS software is overlay constructed with the core resident program making decisions as to what function or operation is requested. At present the basic system contains two startup, eight main overlay, and five special functions programs.

- The startup program initializes the files and system from the user disk.
- The warm start program initializes the system after certain shutdowns or system failures from fixed disk have occurred.
- PROG1 handles most menu hits and digitizing, outputs to terminal, and selects modes.
- PROG2 sets up menu origin and receives numeric inputs from keyboards.
- PROG3 handles the store file, recall file, list file, and new file select functions.
- PROG4 handles the edit functions MODIFY, DELETE, and MOVE except for TRAP MOVE or TRAP DELETE.

- PROG5 handles TRAP MOVE and TRAP DELETE.

- PROG6 SIGNOFF shuts down the system and returns control to the monitor.

- PROG7 has two versions: the main station, which controls, pauses, starts, and restarts the plotter; and the remote station, which intercepts attempts to control the plotter from remote stations.

- PROG8 converts a system drawing file and associated symbol file into a sequential XDOS binary file.

- The background plotting program performs a plotting operation in the background mode. The plot data are output to digital tape for use on the Gerber plotter.

- The polygon output (POLYOUT) program writes the digitized vertices of polygons on magnetic tape for use on other systems. Each polygon is preceded by text identifiers (field number and crop code). The identifier is used as the reference point for the polygons. This program is used in the accuracy assessment task of LACIE.

- The polygon delete (POLYDEL) program deletes a polygon from the current drawing/SCR files.

- The Bendix 100 IDS (B-100) plot program provides a simple means of visually comparing an overlay showing field boundaries and the digitized Bendix 100 IDS data.

- The boundary detection and registration (BDARP1) program provides boundary plots (polygons) from classified data sets. The program will process one class at a time; therefore, for multiple classes, the program must be run for each class desired.

MAP COMPILATION AND PRODUCTION CAPABILITIES

General

The CTL has extensive capabilities for the compilation and production of maps from Earth resources data. The following equipment is used by this laboratory to aid in this effort.

Hardware

FILM VIEWER/READER

The Traid film viewer/reader, Model 100 (V/R 100), is a self-contained system for viewing film images on the screen. This machine accepts roll film of 16-, 35-, and 70-millimeter widths. The film is input, and a 20- by 24-inch visual display and a printout of X- and Y-coordinate measurements and frame numbers are output. A 180° rotation and an image translation in the X- and Y-directions are available.

MULTISENSOR TAKEUP TABLE

The multisensor takeup (MSTU) table is a film-viewing instrument with two separate film tracks. This machine will accept any size film up to 9-1/2 inches and will accommodate transparencies as large as 9 by 18 inches. The film is input, and a visual display is output. Each of the four 10- by 20-inch viewing areas employs a vacuum mask assembly for holding the film flat on the illuminated surface. The MSTU can use any of three Bausch & Lomb optical stereoscopes (Zoom 70, Zoom 95, and the versatile stereoscope).

ZOOM TRANSFERSCOPE

The Bausch & Lomb Zoom transferscope accepts a photograph and map of the same area as input and, by using light intensities, superimposes the two, producing a single image to locate areas or points to be plotted. Annotated maps are output. Lens changes may be used to reduce the transparency viewer by 2 percent and to enlarge the map viewer by 4X. There is also the capability of enlarging both images simultaneously from 1X through 7X.

DATA ADDITIVE COLOR SYSTEM

The Data Additive Color System is a closed-circuit television system that displays black-and-white transparencies on a screen. Color can

be added according to the densities expressed on the film, making it possible to determine areas that probably have the same or similar surface vegetation or cover. Black-and-white film is input, and the visual display with color added is output.

ISS MODEL 600 COLOR ADDITIVE VIEWER

The International Imaging System (IIS) Model 600 color additive viewer accepts black-and-white 70-millimeter film chips and 9-1/2-inch multiband roll film as input. It has a four-channel (clear, red, blue, and green) color filter system to enhance the film being viewed. The output is the visual display, along with the added capability of making a negative or film transparency of the viewed scene.

SINGER-FRIDEN 70T PHOTOGRAPHIC DISPLAY

The Singer-Friden 70T photographic display machine uses conventional 35-millimeter photographic paper and film (without adhesive backing). Alphanumeric lettering is composed using a conventional typewriter keyboard. Four 92-character type fonts are stored in the machine and can be photographically reproduced in 10 different sizes from 12 through 96 points. Ten different type styles are now available, including one Greek and one mathematical font.

VARITYPER HEADLINER

The Varityper headliner is a small type composer using conventional 35-millimeter photographic film or paper with adhesive backing. Alphanumeric lettering is composed manually, one character at a time, using type faces mounted near the rim of a circular disk. Nearly 40 fonts are available, representing a wide variety of type sizes and styles.

KARGL REFLECTING PROJECTOR

The Kargl reflecting projector is a glass-top drafting table used manually to trace on translucent film or paper any graphic material supported on its illuminated stage plate. The stage plate has a useful area of 9 by 18 inches, whereas the table top has a useful area of 24 by 36 inches, depending upon magnification. This projector has a scale-changing capability ranging from 50 to 250 percent and limited tilt-changing capability.

MASTERPIECE DRY MOUNTING PRESS	The Masterpiece dry-mounting 2000-watt hot press has a useful working area of 24 by 30 inches with operating temperatures of 180° to 350° F. It is used primarily to bind maps and photographs to sheets of drafting board by the use of an intermediate sheet of glue-impregnated (dry) tissue paper.
SCHAEFER PROOF COATER	The Schaefer proof coater is used to place a thin coat of hot adhesive wax on any thin sheet of flexible material such as a map or photograph. Sheets less than 20 inches wide are manually fed between a pair of rotating metal rollers and slowly turned by a small electric motor. The bottom part of the lower roller rests in a small tank of melted wax, heated by a 1000-watt element.
OZALID BLUE-RAY MACHINE	The Ozalid Blu-Ray machine is used to develop white or sepia line drawings and images on sensitized paper and stable-base frosted or clear film. The machine handles manuscripts as large as 48 inches in width and operates at speeds up to 30 feet per minute.
VARIFONT 3000 LETTERING SYSTEM	The Varifont 3000 lettering system is a single-step dry chemical typesetter which reproduces map-quality lettering. The machine uses interchangeable fonts covering all standard styles and type sizes (8 to 36 point). It has automatic letter spacing and word alinement capabilities.
NUARC PLATE MAKER	The Nuarc plate maker is a 220-volt flip-top vacuum frame with a built-in vacuum pump, mercury-arc light, and timer with automatic shutoff. It has a useful working area of 44 by 56 inches.
WILD MIRROR STEREOSCOPE	The Wild mirror stereoscope has auxiliary 3X binoculars which are suitable for viewing 9- by 9-inch aerial photographs.

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Data Services

GENERAL

The data services within the EOD provide data and information for Earth resources remote sensing projects. The services are provided through the Data Research and Control (DR&C) Section, which incorporates the following functions: (1) a Research Data Facility (Redaf) performs research on data availability — primarily imagery from NASA/JSC space and aircraft remote sensing projects; (2) document collections include reports on remote sensing programs and provide background information on the Earth sciences; (3) map and chart service personnel locate and order maps and charts; (4) a Landsat full-frame photographic file is maintained to support EOD; and (5) a visual aids file is available for the development of EOD presentations. In addition, the section organizes and coordinates operational data in support of the major EOD remote sensing projects and manages data orders.

RESEARCH DATA FACILITY

The Redaf provides a center for research and viewing of remote sensor imagery and ancillary products generated by NASA Earth resources programs at JSC and other related centers. It is primarily a reference area for NASA and contractor scientists but is open also to the general public.

Data types include filmed remote sensor data from JSC and Ames Research Center (ARC) aircraft missions and from the Gemini, Apollo, Skylab, and Apollo-Soyuz Test Project (ASTP) manned spacecraft missions. A Landsat image file is available also for viewing scenes acquired by both Landsat-1 and Landsat-2. The Landsat scenes have been reproduced in band 5 on microfilm and are accessed through the Landsat World Reference System by path and row nomenclature associated with geographic coordinate locations.

Univac 1108/ Datapoint 3300

A Redaf remote terminal, the Datapoint 3300, interfaces with a JSC Univac 1108. The system is queried for remote sensor coverage through the Univac 1108 data base, which contains information on aircraft photography for NASA/JSC Missions 100 through 278 and on most manned spacecraft missions, including all Gemini, Apollo, and Skylab.

Hewlett-Packard/ Tektronix Image Selection System

The Tektronix terminal in the Redaf provides the capability to query the JSC Hewlett-Packard Image Selection System (ISS) program and data base to locate and identify aircraft photography taken on NASA/JSC aircraft Mission 279 and subsequent missions. Coverage is identified in terms of aircraft image data acquisition parameters.

Microfilm Viewers

All NASA aircraft and spacecraft mission Earth-observing photography and most NASA aircraft scanner data are copied on microfilm. Three Kodak Microstar 16-millimeter microfilm viewers with the IC-5 frame selection control are available for image area search and analysis.

DOCUMENT COLLECTIONS

The document collections in DR&C are related directly to the remote sensing of Earth resources and are available to all EOD personnel, approved secondary users, and other government agencies assigned to EOD programs. Information is held in hardcopy and microfiche form.

Services of this unit include: reference and bibliographic searches, interlibrary loans, document purchase requests and other acquisition methods, assistance in the use of research equipment (including the Recon Data Base terminal), and an archive of project-related material.

Recon Data Base Terminal

The DR&C Recon Data Base terminal interfaces with the GSFC Recon data file of technical publications, which are listed in periodicals such as the Scientific and Technical Aerospace Reports (STAR), International Aerospace Abstracts (IAA), and NASA Thesaurus. Searches are conducted by the DR&C staff, with assistance provided to individual users.

Manual Files

Files for the document collections are maintained by title, author, and selected corporate authors [such as Center for Research, Inc. (CRES), Environmental Research Institute of Michigan (ERIM), and LARS] and by document number.

Microfiche Files and Viewers

DR&C maintains two 3M 400 reader/printers for viewing and printing hardcopies of microfiche and microfilm. Assistance is provided to users. Microfiche of documents listed in STAR as E numbers (Earth resources) are maintained, and holdings start with 1972. A limited number of additional titles in microfiche are also maintained.

MAP AND CHART SERVICES

The map and chart service personnel locate, order, and receive maps and charts from U.S. and foreign map repositories to support EOD Earth resources remote sensing projects. Copies of these maps and charts are maintained in the map library for the life of the remote sensing program. In addition, copies of cartographic and mosaic products developed by the projects are stored and managed by the library.

A semiautomated index card filing system, ACCESS 60, is used in the map library to maintain an inventory of all maps, charts, and mosaics. Approximately 90 000 items are filed in the map library.

LANDSAT FULL-FRAME FILES

The DR&C maintains a Landsat full-frame imagery file in support of all EOD projects and coordinates the use of the corresponding magnetic image tapes. Each image and tape is indexed. The photography is filed by the footprint number obtained from the Landsat World Reference System. Direct contact is maintained with GSFC by TWX to obtain image tapes on special order.

VISUAL AIDS

Over 3300 illustrations in 70- and 35-millimeter, 7- by 9-inch transparency, and 8- by 10-inch print formats are available to serve as aids in the preparation of technical papers and presentations. These aids provide photographs of equipment, management summaries, and technical information developed by the EOD remote sensing projects.

OPERATIONAL DATA HANDLING

DR&C handles operational data in support of all EOD projects. This effort encompasses the coordination of data preparation activities, which include determining map coverage, assembling film products, and developing supportive documentation and statistics, as well as maintaining inputs to status and tracking systems of data flow and handling activities.

Data Packet Files

Data packet files are a mechanism used to assemble and maintain data sets for specific study sites within a remote sensing project. Various systems are used for filing and retrieving, in order to make data available on a timely and operationally efficient basis.

Data Ordering

DR&C manages requests for the development of original graphic arts data and the reproduction of photographic and printed data in support of EOD projects and Redaf. This management includes preparation of request forms, status and tracking through the system, data receipt, quality control checks, and delivery.